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SOCIETY OF FORESTERS OF GREAT BRITAIN

THIS SOCIETY was formed at Aberdeen in 1925 and adopted its first Constitution at Oxford in 1926. This has been modified several times and the present Constitution became operative in December 1947.

The object of the Society is to advance and spread in Great Britain the knowledge of technical forestry in all its aspects.

The activities include the publication of the journal, the holding of meetings, conferences, and excursions, and the awarding of a medal.

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THE IMPORTANCE OF FORESTRY is being realized more and more in Great Britain. The number of foresters is increasing steadily, and a forestry profession is gradually being built up. It is intended that this Society should be representative of the profession. Those who are not engaged in the practice of forestry or the allied sciences are cordially invited to join the Society as Ordinary Members.

THE SOCIETY'S JOURNAL, called *Forestry*, is usually published twice a year, in January and July. It provides a means for the publication of the results of practice and research both in the growing of timber and in its utilization, including such basic sciences as forest physiology and ecology, forest soils, wood structure, and timber physics, and allied sciences such as forest entomology and forest mycology.

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[*continued on inside back cover*

SOME EFFECTS OF SHELTERBELTS UPON LOCAL AND MICRO CLIMATE

By R. W. GLOYNE

(*Meteorological Office*)

SUMMARY

Attention is drawn to recent work on wind and shelter and a comprehensive list of references is given. Diagrams illustrate the main effects of barriers on the flow of air and these effects are discussed. The author then considers shortly the influence of wide tree belts on wind and their other effects such as shade, temperature, and humidity, as they present practical problems to the hill farmer. A diagram gives the isopleths of annual mean wind speed for the British Isles together with corresponding data for individual hill sites. This diagram provides a rough estimate of those regions where shelter would seem a necessity.

INTRODUCTION

An account will be given in this paper of some of the effects upon 'climate' due to shelterbelts—and particularly to the larger type likely to concern the hill farmer. Our understanding of the action of such barriers is less complete and less secure than that which we possess relating to the type of wind-break and shelter screen long familiar to horticulturalists, and the position is further complicated by the fact that the hill farmer is generally concerned with the possible benefits to stock and grass, both of which are very difficult subjects for experimental work.

The flow of air and the flux of radiation are altered by a barrier, and a wide range of physical problems therefore arises, but we shall outline only the influence of a tree belt upon the 'micro-' and 'local-' climate, i.e. the changes in climate which occur respectively in an area up to a few acres in extent, and in a topographical unit such as a minor range of hills, a valley, or an estuary.

In the broadest possible terms the shelterbelt enables us to effect a measure of control over our climate which is more completely achieved by a building: the results are detrimental to the extent that the stagnation of the air and shading are undesirable, and the use of good agricultural land involved.

THE EFFECT OF A BARRIER UPON THE FLOW OF AIR

Those characteristics of air flow which are encountered with actual shelterbelts are indicated in the simplified two-dimensional picture of the effect of an impermeable bluff wall on a current of air approaching it perpendicularly (Fig. 1). In practice the main features of the pattern are found to be similar for wind speeds between about 5 to 25 m.p.h. and for barriers whose height ranges from less than a foot to the tallest of trees, thus we may usefully express horizontal distances as multiples of the height (h) of the barrier.

Ignoring the small zone with up-wind protection, the region of disturbed flow may conveniently be divided into

(*a*) the wind-shadow;

(*b*) the portion beyond this (i.e. the remainder of the 'wake').

In the 'wind-shadow' the flow is characterized by large eddies, which are capable of damaging crops. These eddies drift down stream relatively slowly, until caught up in the region (*b*), where they dissipate more or less rapidly, and where the original flow is eventually re-established as the turbulence induced by the barrier gradually disappears. That two such portions do exist is fairly clearly demonstrated by a variety of phenomena, the most striking being the shape of the drifts of snow behind fences; indeed Finney (9) states that in both wind tunnel and field trials, snow drifts will be confined to the zone occupied by the eddies.

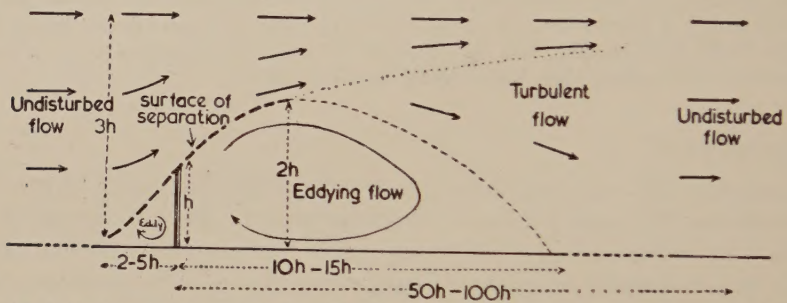

FIG. 1. To indicate some characteristics of the flow pattern due to a near-solid, cross-wind barrier (not to scale).

Broadly speaking, the 'wind-shadow' extends down-wind to 10 or 15 *h* and most workers agree that at about 40 or 50 *h* from barriers of a simple design the incident flow is re-established. Some workers, e.g. Bodrov (4), have identified effects at 100 *h* or more, but certainly in hilly areas other factors such as changes in slope and aspect, in surface roughness, &c., will have intervened to alter the flow, and in any event effects beyond 40 *h*, even if real, are so small as to be of little practical consequence. These results are confirmed by the lack of convincing evidence of 'cumulative' effects from a succession of parallel barriers 40 to 50 *h* or more apart.

With a perforated barrier we correctly anticipate that any eddies would be less well defined and less damaging to crops, although field evidence shows that an eddying region does exist—at any rate until the density of the barrier falls below 40 per cent. The effect of different permeabilities can be judged from some work by Hallberg (13) who has examined the flow behind slat fences of varying densities by means of streamers. From his diagrams it is clear that down-draughts and reverse currents are much less marked with a 50 per cent. barrier than with an impermeable one.

In the literature, the wind speed at any point down-wind is usually expressed in terms of the percentage of the 'free wind' measured at some convenient reference height, and the resulting pattern is broadly independent of the absolute speed of the wind, hence a diagram such as Fig. 2 covers a wide range of conditions.

The data, culled from Russian sources (7), summarizes the results of a large number of investigations. The wind speed to the lee of a solid barrier reaches about 40 per cent. of its original value by 5 *h* and virtually 100 per cent. by 40 *h*; the corresponding values for an efficient permeable barrier are 20 and 100 per cent. In the second case the leakage through the barrier prevents any complete stagnation of air and at the same time displaces the point of minimum percentage wind speed to a distance of 3–5 *h* down-wind: more important, the reduction in wind speed averaged over a zone of width 40 *h* is considerably greater with the permeable barrier.

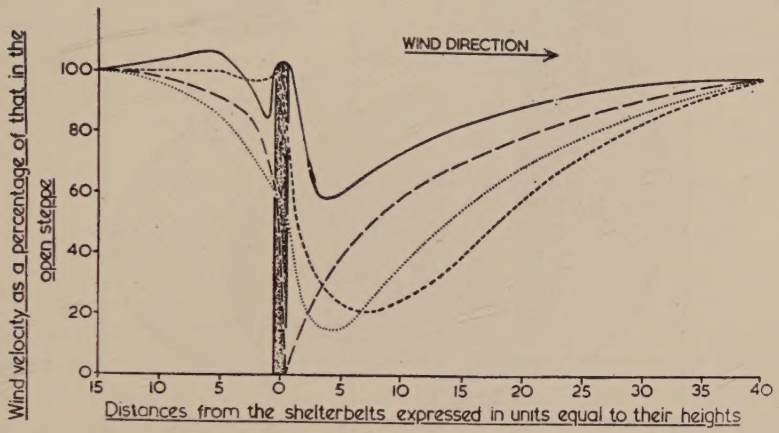

FIG. 2. To show protective effect of shelterbelts of varying permeability.

——— Shelterbelts 'open' throughout their height—partly permeable to wind.
— — — Shelterbelts 'dense' throughout their height—impermeable to wind.
..... Shelterbelts of 'medium density'—slightly permeable below and 'dense' above.
-------- Shelterbelts of 'medium density' above and 'open' below.

Wind speeds are measured usually by means of cup-anemometers, vane type air meters, and sometimes pendulum and pressure plate instruments. These are only strictly comparable in a steady horizontal uni-directional flow, and we must bear in mind the eddying character of the flow, especially with the denser barriers, when appraising the results such as are presented in Fig. 2 where the location and intensity of the eddies are not explicitly indicated.

THE INFLUENCE OF WIDE BELTS ON THE WIND SPEED

The belts appropriate to hill farms are not often of the long and narrow type assumed in the discussion so far. Typical belts for such areas are more likely to be at least 2 chains or more wide composed of 15 or more rows of mature trees, up to large forest type plantations covering hundreds of acres: but equally important are the compact blocks of trees, copses, and 'farmers' corners' which can fulfil an important function on the hill farm.

Field work with such large belts is difficult. To a first approximation the results

quoted in the previous section apply (down-wind distances being measured from the lee-edge). The limited cross-wind extent of copses and small compact blocks of trees renders the end-effects of particular importance, as may be readily appreciated from Fig. 3. Even when the wind strikes the barrier at right angles the flow around the end 'eats' into the protected area, and this is further reduced in extent, if the wind strikes the barrier obliquely.

It is most important to remember that, firstly, the term 'prevailing winds' must be interpreted to include winds from directions within a range centred about a

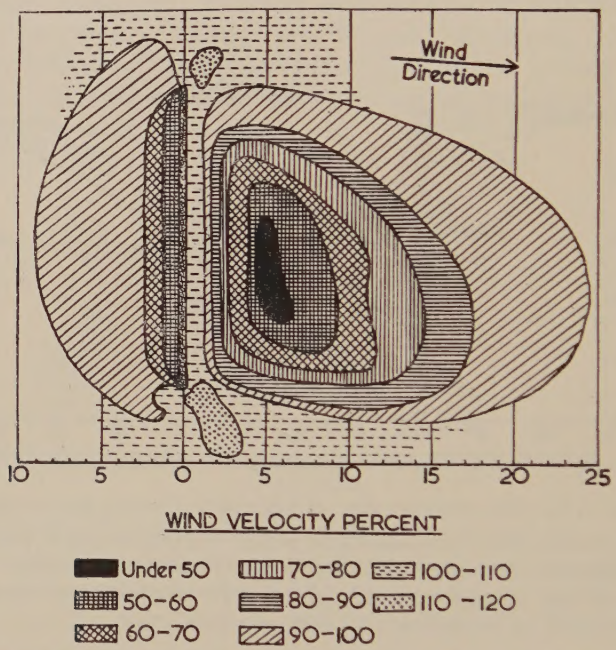

Fig. 3. Wind field (in plan) due to a slat barrier of average density 50 per cent. and 19 barrier heights long (from Bates (2)).

'prevailing' direction, and secondly, that even in freely exposed sites the wind will not blow from the 'prevailing' direction for as many as 50 per cent. of occasions. At the Scillies, for example, the following average distribution of wind direction exists:

Of all winds of speeds	*Per cent. between 225° and 315°*	*Per cent. between 245° and 295°*
>3 m.p.h. . .	37	22
>12 m.p.h. . .	41	24

It may not, of course, be the prevailing winds against which protection is most required—both the shepherd and the grower of early vegetables probably find the cold east and north-east winds of early spring far more troublesome than the stronger but warmer winds from the west or south-west. On the other hand, those

plants whose life cycle extends over many seasons (e.g. fruit-trees) are more likely to need protection against the more frequent stronger winds.

As the wind approaches the belt there is a definite tendency for its direction to become parallel to that of the belt, but more work is needed on this problem before quantitative statements can be made with reasonable confidence: see, for example, Nageli (16), Woelfle (22), Gorshenin (12), Illsley (14), Perring and Cameron (18) and (19).

THE INFLUENCE OF LARGE PLANTATIONS ON THE WIND

As the belt widens so the frictional drag on the air-stream increases, and there is evidence of some accompanying increase in the sheltering efficiency of the barrier. Nokkentved and Flensborg (17) have compared the reduction in the wind speed on the lee sides of plantations less than, and greater than, 2,000 metres wide (about 2,200 yds.) with the following results:

	Distances at which wind speed increases to	
	60 per cent. of the 'free' wind speed	*100 per cent. of 'free' wind speed*
Group I (<2 km.)	15 *h* (8 *h*–23 *h*)	30 *h*–40 *h*
Group II (>2 km.)	19 *h* (9 *h*–27 *h*)	60 *h*–70 *h*

They comment that in passing over wide plantations the wind tends to be stabilized and 'lifted into the air', after which it leaves the lee-edge horizontally 'so that the subsequent mixing with the air in the sheltered area will take place slowly'. In any event there must be a marked and continual frictional dissipation of the energy of the wind by the tree canopy and the downward transfer of energy from progressively higher layers.

It was earlier stated that cumulative effects do not occur, at any rate with narrow belts, but it still remains true that the speed of the 'free' wind is reduced by the frictional drag of natural and artificial obstacles on the surface. The Danish workers, for example, often stress the advantages which follow a reduction in the general wind speed by well-wooded countryside and in one place remark: 'Whilst in respect of crops the benefit of shelter is confined to the owner of the fields in question, the absence of shelter falls as much on others as on the owner who neglects his belts' (17).

On the general question of multiple barriers, Bates (3) considers that their most important effect is to create a 'larger coherent mass of stilled air' with a 'zone 7–12 *h* stretching laterally from the ends giving some small degree of protection': this clearly implies a sharp reduction of the end-effects.

It is suggested by Nageli (16) that with wide belts the minimum wind speed occurs within them, although the specific examples he quotes do not seem adequate to establish this as the general rule.

It also appears true that although the down-draughts inseparable from the *narrow* impermeable barrier do occur, they are much less marked with the wider type of shelterbelt.

The matters touched on in this section are especially relevant to the hill-farming

problem in which shelter plantations, blocks, and copses are regarded as at least as important as long narrow belts (Cadman (6)).

THE EFFECT OF A BARRIER UPON OTHER CLIMATIC ELEMENTS

A barrier will cast a sun shadow, thereby influencing radiation and illumination and moisture relationships. These, in association with the changes in the wind, will lead to consequential changes in all other features of the climate. The deposition of air-borne material is also influenced.

The direct shading, which may be beneficial to livestock in high summer, is usually an unfavourable feature in the winter and early spring. A considerable area in the north of an east-west barrier will enjoy very little winter sunshine, whereas a north-south barrier erected against damaging winds from west or east will not give rise to a permanently shaded area. From the point of view of shade therefore, a belt of deciduous trees is to be preferred to a coniferous one. It cannot be too frequently emphasized that the influence of a belt can be assessed only after considering all aspects, and the interaction between shading and wind-protection must be regarded as fundamental.

Shaded portions will dry out more slowly than unshaded areas, and will also tend to retain any snow drifts and hence experience lower soil and air temperatures in the spring. Nevertheless on 'light' soils these tendencies—particularly the retention of moisture—may be advantageous.

Bates (1) reported from the United States that on sunny days with light to moderate winds maximum temperatures at 4 feet in the zone between 2 *h* and 5 *h* behind a dense barrier exceeded those in the 'open' by 2–5° F., and minima were about the same amount *less* at night, little difference being found beyond about 10 *h*. Under our conditions of intermittent sunshine the differences obtained are less and of course rarely occur day after day. Some recent figures from Holland (21) indicate maximum differences up to 5 or 6° F. about 4 inches from the surface but 1–3° F. at 4 feet within a zone about 10 *h* wide. On balance over the 24 hours the mean temperature will be slightly higher in the protected than in the unprotected zone, unless the belt is so situated as to create a miniature 'frost pocket' on still nights. In contrast, if the sheltered side of a belt is also the unshaded side then undesirably high mid-afternoon temperatures may result. With strong winds and/or overcast skies temperature differences tend to disappear.

Soil temperatures will be more closely linked with the position and intensity of the shadow than will air temperatures. In the lee zone, just beyond the limits of this shadow, day maxima at 4 inches depth are likely to be between 1° and 5° F. higher than in the 'open': differences nearer the surface will probably be greater.

The thermometer in the meteorological screen, however, is far from being an adequate index of the reaction of humans and livestock as regards heat exchange and hence general comfort (see Brooks (5), Conrad (8)). The 'temperature in the sun', the wind strength, and the humidity are all involved, and this is an appropriate point to suggest that there is much to be gained from a careful examination and redefinition of the many concepts which are apt to be listed under the single heading 'exposure'.

HUMIDITY AND EVAPORATION

It is the general experience that both the absolute and relative humidities are higher in the protected than in the unprotected zone—once again differences beyond 10 or 15 *h* being of little practical consequence. Under conditions when the vapour pressure near the surface ranges between 7 mm. and 12 mm. of mercury, we may expect to find increases of up to about 2 mm. during the day within a 10 *h* wide strip (21); at night there is an associated heavier fall of dew (Kreutz (15)).

Relative humidity by day in similar circumstances would be greater by 5–10 per cent. except when unusually high temperatures develop in unshaded but sheltered areas, when it could be less. A similar result has been reported by Bodrov (4) in the lee of a dense barrier where the intense turbulent mixing transported water vapour rapidly from the protected area.

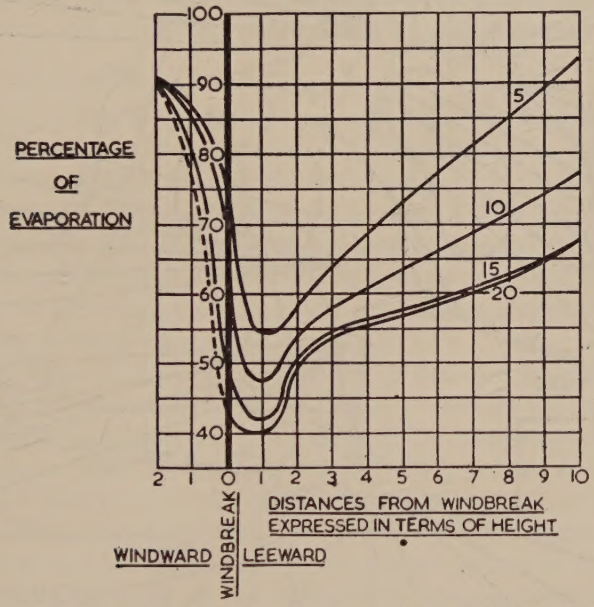

FIG. 4. Protective efficiency of underplanted cottonwood groves for various wind velocities of 5, 10, 15, and 20 m.p.h. Average height 75 feet; 70 readings.

A great mass of data exists relating to evaporation in the vicinity of barriers. A typical diagram showing relative water loss from a continually moistened sheet of filter paper in a dry climate is given above in Fig. 4 (1). The shape of the curve is similar to that for wind reduction although the direct effect of shading is clearly marked, but the contrasts are less, do not extend so far as do those of wind speed, and involve the absolute value of the speed.

A more careful examination, however, reveals many difficulties:

(*a*) the loss of water from any type of evaporimeter is difficult to express in terms of climatic elements, and involves the dimensions and shape of the instrument and the methods of exposure;

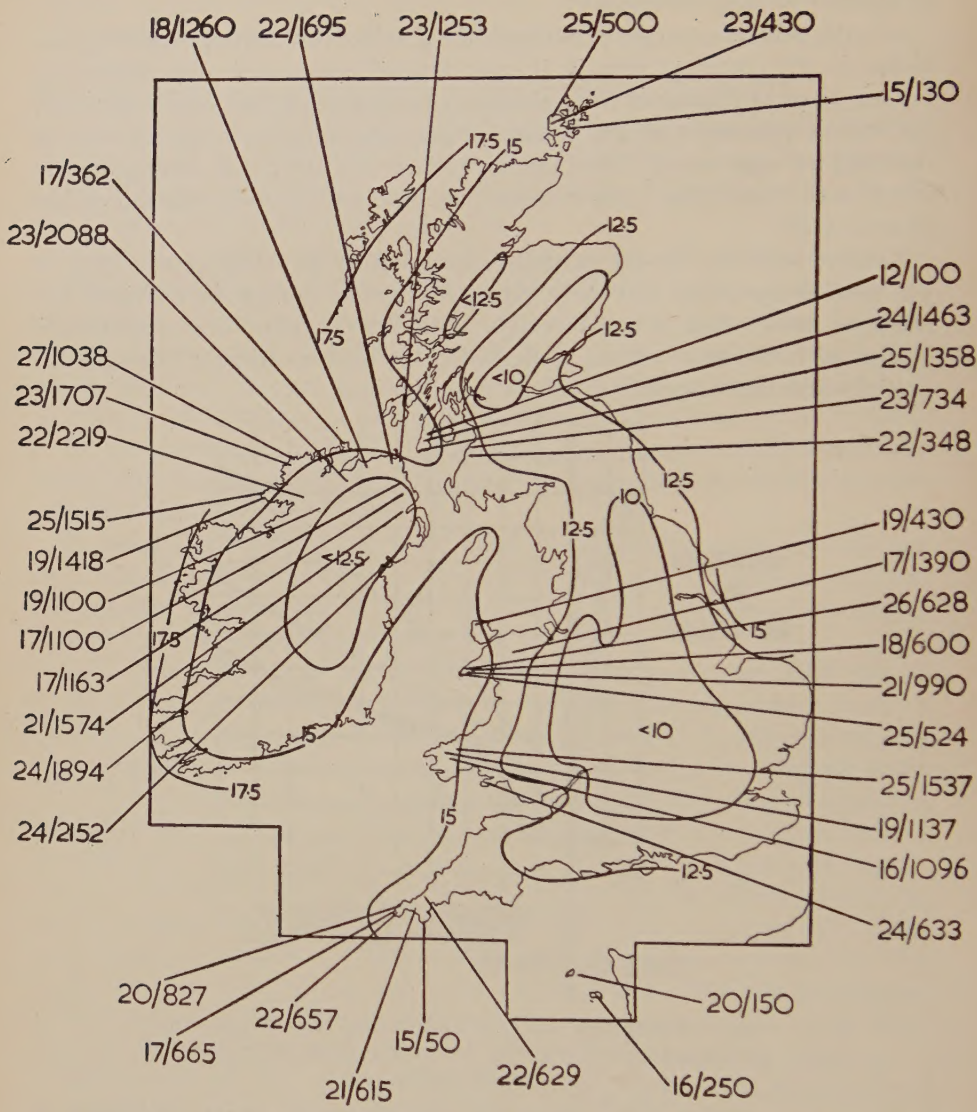

Fig. 5

Isopleths of average annual wind speed together with corresponding data for individual hill sites: e.g. 27/1038 means 27 m.p.h. on a hill summit 1,038 feet above MSL. From *Climatological Atlas*, Meteorological Office (London) and from Golding and Stodhart, Electrical Research Association, Rep. C/T 108 1952 (Lit. Ref. II).

(*b*) intercomparability between the different types is achieved only by means of rather arbitrary and empirically determined conversion factors;

(*c*) it does not necessarily follow that any of the modes of measurement give a quantitative estimate of the evaporation from the ground or transpiration from plants.

There is, however, sufficient qualitative agreement, and weighty confirmation from biological studies, to establish that within a 5 *h* to 10 *h* zone (perhaps to 20 *h*) the evaporative 'potential' imposed upon the soil or plant is reduced by the interposition of a barrier.

In the spring this reduction in wind and in evaporation, and the slightly higher temperature and humidity all help towards the production of the desired 'early bite' which will often be found on the side protected against the cold dry east and north-easterly winds of winter and spring, whereas later in the year protection against the west and south-west winds may bring more practical advantages.

PROBLEMS THAT ARISE IN PRACTICE

The example of the 'early bite' serves to emphasize the fundamental principle that on any given occasion it is the general weather situation which will determine the extent to which the potentialities of any particular belt can be realized. Geiger (10) expresses it thus: 'In general a decrease of the wind force by artificial means causes a strengthening of the local climatic characteristics. The practical result depends entirely on the individual case,' and we can scarcely over-emphasize the necessity for appraising the general climatic and topographical features of the site in which a particular shelterbelt occurs.

At an early stage in any projected scheme of planting we need to seek some guidance as to whether shelterbelts are desirable from the agricultural point of view. For this purpose the extent of the deformation of existing trees provides invaluable evidence. Cases abound in the British Isles, and the writer has, for example, noted deformation on two of the Ministry of Agriculture's Experimental Horticulture Stations (at Camborne, Cornwall, and Fairfield, Lancashire) where it is known that annual average wind speeds of 14 m.p.h. and 12 m.p.h., respectively, occur. Additional evidence on the relationships between wind-speed and tree deformation is given by Putnam (20).

From information such as this it appears clear that at an annual average wind speed of 15 m.p.h. or more (ranging from about 12 m.p.h. in summer to 20 m.p.h. in winter) certain types of trees will be seriously deformed, and by implication the yield of crops and perhaps livestock appreciably reduced.

The diagram reproduced opposite (fig. 5) which gives the isopleths of annual mean wind speed will therefore provide a rough estimate of those regions of the British Isles where shelter would seem a necessity. Of course, contour, slope, and aspect will modify the general picture appreciably (the lush woods in the sheltered east facing valleys of east Cornwall are an example of the ameliorating influence of local features). In addition there are given on the map the estimates of the corresponding averages for various hill sites (11) from which it is clear that even inland shelter may be necessary in hilly areas. The data quoted were obtained

on sites where 'even the heather or grass is clipped very short—seldom higher than 6–12 inches'—suggesting that these speeds are probably above the limits for satisfactory crops.

The writer has frequently formed an estimate from this map of the probable degree of tree deformation to be expected at a given site and within his limited experience this estimate has almost always been confirmed during a subsequent visit. Such errors as do occur are often underestimates of the degree of actual wind damage, for this may readily occur when a minor topographical feature or other natural or artificial obstacle deflects and/or canalizes the wind in areas which are generally immune from wind damage. It appears that valleys of quite limited extent and depth may very definitely canalize the wind to the extent necessary to cause tree deformation (the Long Ashton Research Station near Bristol lies in such a valley).

Most authorities point out that for livestock the dense barrier is more efficient than the permeable one, particularly if, as has already been stated, vigorous down-draughts do not occur with *wide* impermeable belts of trees. The permeable belt which protects a larger area more efficiently, as well as involving less shading, is generally to be preferred for crops. Livestock can obviously seek those areas which are protected and can therefore utilize the relatively restricted zone associated with blocks of trees, copses, and so on.

The hill farmer may experience difficulties arising from the deep snow drifts which tend to form near belts and plantations of trees, and also from variations in the depth and frequency of frozen soil associated with changes in depth of snow cover.

CONCLUDING REMARKS

Although in any discussion one cannot avoid treating each climatic element separately, it should be clear that in any practical case all factors involved and their interactions must be considered, and in such a survey a full appreciation of the broad climatic and topographical features is as essential as is the estimate of the 'local' and 'micro'-climatic effects which the shelterbelt is expected to produce.

Valuable information can be obtained from a study of the patterns of land use; of the distribution of vegetation and peculiarities of animal behavour (i.e. using plants and animals as climatic 'indicators'); and by giving adequate weight to local 'lore', to the design and siting of existing buildings and of other structures such as old windmills.

Whilst there is room for differences of opinion in particular cases, there can be no question of the potential value to food production in the British Isles of shelterbelts and windbreaks.

ACKNOWLEDGEMENTS

This paper, which is based on one read before the British Association in Liverpool in 1953, is published with the permission of the British Association and of the Director of the Meteorological Office.

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NOTICES

The Climates of the Continents. Fourth Edition. By W. G. KENDREW. Oxford at the Clarendon Press, 1953. Pp. 607 with 194 maps and drawings and numerous tables. Price (in U.K. only) 50*s.* net.

THIS well-known book, recognized as containing the most useful and convenient collection of climatic data available in the English language, has been enlarged and entirely reset for this edition. Many sections have been rewritten to bring the treatment up to date. Nearly all the climatic means have been revised, and data for many new stations added, useful material having become available in recent years as the result of the demands of air-navigation in peace and war. Several new tables are included of wind-directions, diurnal temperatures, sunshine, fog, and other elements, to provide a broader foundation for the detail which the practical worker on any area requires.

Primary sources are the basis of the work; data have been obtained both from official publications, now numerous as a result of the recent war, and by inquiry and search at meteorological offices, in particular the British. Secondary sources have been intentionally left aside with a few notable exceptions such as the *Handbuch der Klimatologie* of J. Hann and the more modern work with the same title edited by W. Köppen and R. Geiger.

An attempt has been made to choose for more detailed description regions of significance in the world's present turmoil or likely to be prominent in the future.

Shelterbelts for Welsh Hill Farms. By W. A. CADMAN. Forestry Commission Record, No. 22, 1953. Her Majesty's Stationery Office. Pp. 32 with 5 photographs and 9 diagrams. Price 2*s.*

THIS timely record aims to give to hill farmers guidance with their special problems of severe exposure on the relatively poor acid soils on upland farms in Great Britain. The writer distinguishes between shelter for farm crops generally in enclosed fields which can be achieved by fairly narrow belts permeable below the crowns and shelter for stock on the open hill where wider, denser belts are needed. The selection of sites and the shape of belts both in relation to length of stock-proof boundary and effectiveness as shelter are given ample consideration and well illustrated with diagrams. There is a section on the choice of species which should prevent the worst mistakes being made and some examples are given of suitable composition by species. A further section discusses the work to be done before and after planting. The record ends by pointing out how shelterbelts can help to provide stakes, rails, &c. for use on the farm and perhaps more important still where advice about these belts can be obtained and what grants towards cost are obtainable under The Hill Farming Act 1946, The Livestock Rearing Act 1951, and The Forestry Act 1951. There is a useful bibliography.

GALES AND GALE DAMAGE TO FORESTS, WITH SPECIAL REFERENCE TO THE EFFECTS OF THE STORM OF 31ST JANUARY 1953, IN THE NORTH-EAST OF SCOTLAND

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SUMMARY

The storm of 31st January 1953 caused the wind-throw of over 45 million cubic feet in forests in the north-east of Scotland, mainly of coniferous species. Some general features of the wind climate of the country are discussed and it appears that, although gale risk is a serious factor in forestry in the region, very few gales during the last 250 years have attained a violence comparable with the recent storm. The local distribution of extreme gusts modified by topographical features is considered to be the principal cause of the varying degree of damage. There was a marked correlation between height of the trees and wind-throw; few stands under 40 feet in height have been damaged. Different species have also reacted differently and this is discussed. Of the edaphic factors the effect of compacted soil horizons on depth of rooting has clearly been important. Finally the influence of layout and tending are discussed, and it is concluded that wind-resistant margins are important in the prevention of gale damage. In the less-extreme cases of damage, the effect of different factors influencing gale damage accords with previous European experience which is reviewed.

INTRODUCTION

THE storm of 31st January 1953, whose effects were catastrophic in different ways over large regions of north-west Europe, did unprecedented damage to woodlands in the north-east of Scotland. This has already been discussed by Steven (46, 47) and Lines (33). The effects of this gale are important from many different points of view, such as the financial loss to private forest owners, the immediate problems of salvage and control of potentially dangerous insect pests, the longer-term problems of the reconstruction of partially damaged woodlands, and the fundamental question of how forests can be made more resistant to gale damage. This article deals with the last.

The location of the British Isles makes gale damage a constant threat to woodlands. The analysis of the effects of a single gale can only give limited data, and moreover this gale was so extreme that the effects of certain factors which might be important at moderate wind speeds were obliterated. Accordingly the conclusions reached from other gales, as recorded in European literature, have been considered along with the field observations and analysis of the effects of the gale of 31st January 1953. Even thus the conclusions reached can only be considered tentative in most instances. Information about previous gales that did serious damage to woodlands is given in Appendix I.

[1] Mr. K. F. Andersen, a British Council Scholar from Denmark, was engaged in the study of the effect of wind on trees and stands during the Session 1952–3, when the disastrous storm took place.

METEOROLOGICAL CONDITIONS

General data for Scotland

Regular meteorological recordings of speed and direction of wind are made at a relatively small number of places in Scotland. Moreover continuous recordings with anemometers as well as direct estimates are largely confined to coastal areas, which, in conjunction with the varied configuration of the country, makes a true assessment of the actual wind-flow difficult. In comparison with most other countries, however, the wind data for the British Isles are good, and readily available from the Meteorological Office.

From the point of view of forestry, two aspects of the wind climate are of importance: the average level concept, which is directly limiting to tree growth; and the maximum attainable speeds which determine the risk of wind-throw.

The average wind. The over-all decline in wind speed from the exposed west coast to the east is the striking feature. The annual mean, expressed in m.p.h. (13, 36) is approximately 18 in the Outer Hebrides, 15 along the coast of the mainland, 12–13 east of the Great Glen, and decreasing to less than 10 in the central parts of Aberdeenshire, Angus, and Perthshire. A local maximum lies along the east coast.[1] This general trend in wind régime is partly parallel to the exposure zones proposed by Anderson for Scotland (2). The discrepancies between average wind speed and exposure as measured by the forest vegetation may probably be attributed to the difference in drying effect of winds from different directions. For the important spring months March to June, there is a much higher frequency of easterly winds on the east coast than in the west (Fife: 24 per cent., Tiree: 10 per cent.) (5, 36). Generally, however, the south, south-west, and west winds together average about 50 per cent. in the country as a whole, and are in fact the real makers of the wind climate of Scotland.

The extreme winds. Up to a point the frequency of gales is correlated with the average wind speeds. In meteorological terminology, gales are winds with velocities greater than 39 m.p.h. This figure may also be taken as the limit for winds causing damage in forests under other adverse conditions. The pattern over Scotland is the same as that for the average values, the number of days with gales, decreasing from north-west to south-east from over 30 to less than 5 a year (36). In general, the mean annual wind speed is an adequate figure for expression of the total wind climate, as the frequency distributions of winds are very similar for all localities (13). As trees to some extent react to the general exposure to wind with an increase in mechanical stability of roots and in stems (20, 38 a.o.), the actual differences in the danger of damage to forests is smaller than the gale frequencies indicate.

The largest proportion of gales occurs during winter, approximately 80 per cent. (5), and there is a tendency to a concentration in the south-west quadrant. Moreover, the gales from easterly directions are to a great extent confined to the spring and summer and do not reach as high levels as the midwinter gales (5).

Severe gales, that is mean wind speeds above about 50 m.p.h., occur regularly

[1] See isopleths of average annual wind speedin diagram in R. W. Gloyne's paper on page 92 of this number of *Forestry*.—Editor.

in most places of Scotland, and are of special importance for forestry. They are almost totally absent during summer. Their frequency along the coast based on short-time estimates of Beaufort speed varies from 6–8 days a year in the north to 4 along the north-west coast and 2–3 in south-east (5). If the annual records of highest hourly mean speeds (25) are examined it will be found that their average level is 50–60 m.p.h. on the western and northern islands and on an exposed site like Bell Rock on the east coast, and 40–50 m.p.h. in the rest of the country, except for the central part, where the mean wind speed only exceptionally reaches 40 m.p.h. Thus there can be seen an exposure pattern very similar to the distribution of average wind speed. The relative probability of severe gales can be estimated to be 1: 2: 4 respectively in the Central-north-east Highlands, the West Highland and Central Lowland, and the coastal areas of west and north.

The apparent sheltering effect of the land masses is, however, less than these figures indicate. Wind damage in forests is primarily dependent on the force and the frequency of the gusts, and the gustiness of a wind increases from the coast inland (5, 25). This means that a gale blowing 40 m.p.h. in the interior may have the same gust-level as a coastal gale of 50 m.p.h. and approximately the same damaging effect. This difference, which actually is a difference in turbulence of the wind, can be traced on the automatic recordings of anemographs, the 'band' being broader for inland stations. It must, therefore, be expected that the differences in wind climate between coast and inland are partly equalized as regards extreme speeds.

Recordings of extreme gusts (5, 25, 36), together with figures for 31st January 1953, suggest that there are no places in an open situation in Scotland which do not occasionally experience gusts of 90 m.p.h., and even the 100 m.p.h. level is not infrequent. It may be assumed that potentially destructive gales may occur everywhere in Scotland. Their frequency is, however, unpredictable. Records from Europe and from this country (Appendix I) seem to show that gale catastrophes may be absent for long periods and reappear again at short intervals during a decade or two.

Other factors. Although the effects of topography and soil will be treated in later sections, it may be appropriate to mention a few features which touch the meteorological aspect of the question. In the first instance it is necessary to stress that measurement of wind speeds takes place in 'open situations', which are neither unduly sheltered, nor extremely exposed. Unfortunately no records are available for the sheltered valleys and glens in the Highlands, but a considerable reduction of the average as well as the maximum speeds may be expected. Records from mountain summits include observations from Ben Nevis (48), which with 261 gales a year above 50 m.p.h. probably represents the severest wind-climate in Britain. Recent observations on hills on the west coast (14) show annual average speeds up to 25 m.p.h.

Climatic factors other than actual wind-speed influence the danger of wind-throw in forests: High rainfall and mild winters cause periodic saturation of the soil, and frost does not occur sufficiently often to secure a firm root hold during late winter, as is the case in several parts of the Continent (7). The high humidity

and long vegetative period may furthermore accelerate the height growth to such an extent that mechanical stability lags behind (11).

Comparison with continental Europe

The wind climate of Scotland is comparable to that of north-west Europe in general. Most important are gales caused by deep Atlantic depressions moving eastwards across or near the mainland. This type of gale, usually from west or north and mainly confined to the winter months, causes the largest part of destruction also in neighbouring countries. It is, however, apparent that 'Atlantic' gales occur with greater frequency and higher average velocity in Scotland than on the Continent, and are a more normal feature of the climatic environment. Scotland is, on the other hand, not exposed to the wind disturbances which may accompany very severe thunderstorms, which, for example in Germany, may reach extreme force and occur from unpredictable directions. Neither do occasional foehn-winds cause havoc in the Highland glens as is the case in the valleys of the Alps and the Carpathians. The regularity of high winds in Scotland and the consistency of shelter and exposure at a given locality are important in preventing gale damage to woodlands.

Data for the storm in Scotland, 31st January 1953

The meteorological data for Scotland on the day of the storm have been analysed in detail by Steven in *Weather*, June 1953 (47), and most of the following particulars as well as figs. 1 and 2 (Plate VI) have been taken from this source, by kind permission of the Editors of *Weather*.

The Meteorological Office has made available other data for three stations within the region where the woodlands were damaged: Kinloss, near Forres on the Moray Firth; Dyce, near Aberdeen; and Leuchars, at the mouth of the Tay in Fife. These stations are all near the coast, but while average wind speed inland might have been less, expectation is that gustiness would be greater. The records for Kinloss show what were the wind speeds when the storm struck the mainland. Dyce is near the area where the catastrophic damage was caused, and many of the worst affected woodlands are within 25 miles of this station. Topographically, the Dyce station is slightly sheltered to the north and north-west by rising ground, and the data should not overstate, at least appreciably, the wind speed and pressures which caused the devastation. The data for Leuchars give a picture of the wind conditions at the southern limit of the region in which the woodlands were damaged, and the reduction in speeds caused by friction as the wind passed over the land surface. Fig. 1 records the hourly average wind speeds on 31 January for these stations. These data show, as was to be expected, that high wind speeds were reached first and the peak was attained earlier at the most northerly of these stations. At Kinloss, the peak was between 0800 and 1000 GMT, at Dyce, between 1100 and 1200, while at Leuchars the speeds were more uni-

FIG. 1. Average hourly wind speeds for each preceding hour from 0000 to 2400 hours on 31st January 1953, for Kinloss, Dyce, and Leuchars stations, based on data supplied by the Meteorological Office, and published by courtesy of the Director.

FIG. 2. Anemogram for 31st January 1953, for Dyce Station. The height of the wind-vane of the Dines Pressure-Tube Anemograph is 225 feet above mean sea level, 40 feet above the ground, and 30 feet above the anemograph hut.

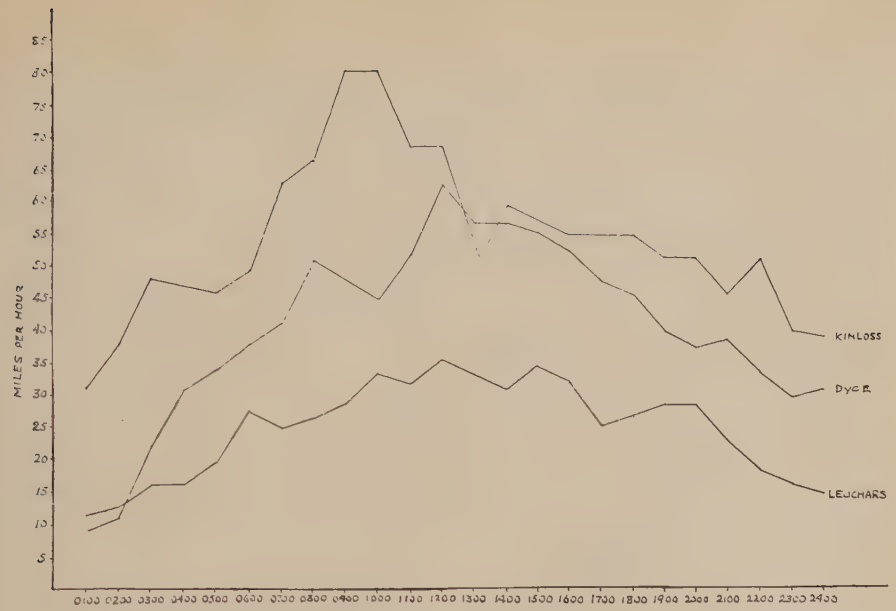

FIG. 1

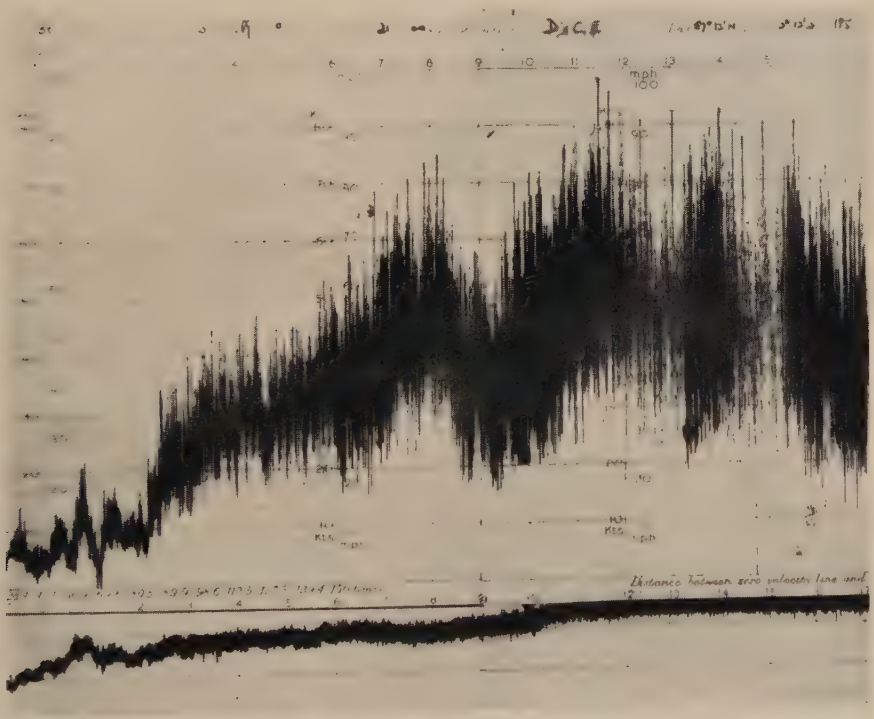

FIG. 2

The details in Fig. 1 and the anemogram (Fig. 2) were supplied by the Meteorological Office and are published by courtesy of the Director. Both figures are reproduced by kind permission of the Editors of 'Weather', from 'Wind and the Forest' by H. M. Steven, in 'Weather', June 1953.

PLATE VI

form as well as much lower. The time of the day when the peak of this storm was reached is unusual. Gold observed that none came in the forenoon (25).

During the storm, the wind direction varied from west-north-west to almost north. Both at Kinloss and Dyce the average direction for the hour ending 0100 was 250°; at 0400, 280°; at 0700, 300°; at 1000, at Kinloss 340°, and at Dyce 310°; at 1300, 350° at both stations; the variations thereafter were small. The pattern at Leuchars was similar. This change in direction before exceptional wind speeds are reached has been commented upon previously (25).

All the evidence indicates that the devastation that this storm caused in woodlands was due to the high wind speeds reached during the gusts, combined with their frequency. Fig. 2 reproduces the anemogram for 31 January at Dyce. This shows that gusts over 80 m.p.h. were recorded from 0800 until 1700 GMT. At the height of the storm during the hour ending 1200, when most of the damage was done in the surrounding area, gusts over 81 m.p.h. were frequent, there were several over 92 m.p.h., while the maximum wind speed was 101 m.p.h. At Kinloss, gusts up to 98 m.p.h. were recorded during the hours ending 0900 and 1000 which marked the peak of the storm there, while the highest gust at Leuchars was 72 m.p.h. at 12.20, again indicating the reduction in speed as the storm passed southwards over the land.

As the rainfall during January 1953 was less than normal over most of Scotland no additional effect of water saturation of the soil can be assumed. The small amounts of snow and sleet accompanying the storm did not to any extent cling to the trees and can only be expected to have acted as a minor factor, increasing the average density of the air masses and possibly also transferring some kinetic energy from faster moving air in higher altitudes.

The number and duration of the exceptional wind speeds on 31 January are probably unprecedented, and are the reason why the devastation in the woodlands has been so serious (47).

THE EFFECTS OF PHYSIOGRAPHY ON GALE DAMAGE

Review of literature

The meteorological recordings of wind speed and wind direction take place at sites undisturbed by any outstanding features of the landscape, hence the pattern described in the previous part is subject to large local deviations. The character and the magnitude of the influence of changing contours upon the actual wind-field are relationships which have only been studied so far to a small extent. Furthermore, evidence from different sources does not always agree.

The connexion between physiography and wind régime can be and has been studied in several ways: on models in windtunnels (42); by actual wind-measurements in the field (13, 14, 23, 42, 57); and by observations of the reaction of the forest itself (33, 42, 55). Experiments with wind in the laboratory have, however, not given results applicable to natural conditions, because it is impossible artificially to copy the wind structure in a meteorological sense.

Investigations in Britain and U.S.A., in connexion with the establishment of wind power units, and in Germany directly as regards the exposure of forests, permit a number of conclusions to be made. An isolated hill, which is relatively high compared with its horizontal extension, tends to be by-passed by the wind

rather than overflowed (23). The maximum wind speeds occur on the flanks of the hill, a marked minimum at the lee, and a secondary minimum at the windward side. If, instead of a hill, a ridge lying at right angles to the wind direction is considered, the wind is forced to blow over the summit. This involves a considerable acceleration of speed, the speeding-up factor depending on steepness and roughness of the windward slope. It may reach values about 150 per cent., but is probably in most cases less than 125 per cent. (13, 14, 42). Canalization of wind, often connected with a change in direction and locally with an acceleration of speed is a feature which has frequently been observed and which plays an important part in exposure (5, 27, 33, 50, 55). Shelter seems mainly to be dependent on steepness of the sheltering hills. It is assumed that leeward slopes below 8° are unprotected (57). It has been suggested that the sheltered zone behind the summit of a hill is restricted to a few hundred yards, according to the steepness of the slope, and is followed by a region with increased wind speeds (55). This, and the occurrence of wind-throw at the foot of hills, is not fully explained, but may be interpreted as effects of increased turbulence and changes in the vertical gradient of the wind. In mountain regions with relatively large height differences, it is obvious that exposure must change rapidly between very severe and negligible. On the other hand, the influence of wind is on the whole smaller than over flat country, because the roughness of the surface has a general braking effect (24). Investigators have found also that the relative height is of far greater importance than the absolute elevation above sea surface (14, 33).

If increase in wind speed up to and beyond gale force is not accompanied by a complete change in the structure of the wind, it must be expected that gale damage in forests will reflect the influence of contours on the wind field. General experience and investigations (55, 57; see also 33) show that the correlation is marked. According to these, the severest damage occurs where a funnel effect is produced. The lee-facing slopes have a sheltered zone, beginning somewhat below the summit, and a damaged zone, where the over-flowing wind is supposed again to meet the earth's surface. On the wind-facing hillsides the throw is never observed to reach from foot to summit, but is confined to an assumed region of turbulence on the lower slopes and the very exposed tops. For the sake of comparison it is necessary to mention that the cases studied were results of ordinary gales, not of hurricanes.

Evidence from the storm in Scotland of 31st January 1953

The area which has suffered damage can, as regards the character of the land, be divided into three regions, which show certain differences in type and extent of the wind-throws.

The Central Highlands, comprising the Cairngorms and their highest foot-hills, is at the margin of the area concerned. No measurements of wind speeds are available for this part of Scotland, but meteorological observations for the country as a whole during the last days of January 1953 suggest that the gale level was lower inland than farther east. It is, however, unlikely that meteorological factors only are responsible for the rapid decline in damage, which takes place in the

upper valleys of Dee and Spey, that is from Ballater and Grantown-on-Spey upwards. Topography must be assumed to have played an important part, generally reducing wind velocity and affording local shelter. Wind-throws occur as single trees or in groups. Large-scale devastations are not met with, since no extensive woodlands have been uniformly exposed to the full force of the gale. The absolute height above sea level has not had any influence.

The country east and north of the mountain region is characterized by its relatively high rounded hills and ridges and broad river valleys. In this region, physiographical factors had the most pronounced effect; any kind of shelter had a definitely reducing influence on the severity of the damage, while on the other hand specific contours increased it. To this latter category belong the tributary valleys to the Dee from the south. Compared with the surrounding country the wind-throws were extensive: Glen Muick (Altcailleach Forest), Glen Tanar, and Glen Dye. The main reason for this pattern is considered to be a funnel effect exerted by these valleys. The situation of the forests is generally of deciding importance. Woodlands on slopes facing south or south-east are mainly undamaged, probably because the average steepness was sufficient to give effective shelter. On the contrary, devastation is serious on most slopes exposed to the gale. Accordingly, a common picture is a more or less completely flattened northerly and an untouched southerly slope. This feature accounts for most of the uneven distribution of gale damage. Modifications of this general pattern have, however, been noted. Damage may extend from the foot of the north slope to the contour of the summit where it ceases, or it is confined to the middle slope. Scattered blows may occur in the lower zones and are probably connected with soil conditions and impeded drainage. Special conditions are reflected in the distribution of damage, for instance where wind-blows occur in a pass-like formation. (See Appendix II.) The very few cases where forests on a lee facing slope have been affected by the gale seem to occur where the wind came over the top of the hill unhindered by forest vegetation and met this a few hundred feet down the slope.

The landscape east and north of the foot-hills belongs to the more wind exposed regions of Scotland. The country is flat to gently undulating and yields no shelter against gales. Although the woodland area is not extensive it is very seriously damaged: Haddo, Fyvie, Dunecht, and Crathes. This is presumably caused by the lack of topographic obstacles. Apparently the wind has followed the ground smoothly and on gentle south slopes damage is frequent. A special feature of this region is that some of the most exposed woodlands have proved relatively wind-firm, particularly small areas on the top of low hills. The reasons for this are discussed in the section on lay-out and structure of forests.

EFFECTS OF SOIL CONDITIONS AND ROOTING

Review of literature

As a rule wind-blow takes place as uprooting. The frequency with which windbreak instead of uprooting occurs for a given species is due partly to stem factors, such as the incidence of rot and forks or compression faults caused by previous gales, but mainly to firmness of rooting; the greater the firmness of rooting, the

greater the chance of breakage. This is conspicuous where trees are rooted on rocky sites and are able to penetrate through vertical fissures. It is even more marked on deeply frozen soils, and in northern continental countries gale damage from midwinter to spring is limited to breakage (7). There are considerable differences between species in their liability to break: Norway spruce (*Picea abies* Karst.) being less resistant than Sitka spruce (*P. sitchensis* Carr.) and Silver fir (*Abies alba* Mill.) (31), and still less than Scots pine (*Pinus sylvestris* L.) and larch (*Larix* spp.).

Ordinarily, however, gale firmness is closely related to the rooting capacity, which depends partly on specific characteristics, and partly on soil properties. The recognized differences between species regarding their rooting habits must not be exaggerated in this connexion. It is more a question of specific reactions to different soils than of fixed and uniform root systems. The soil in the widest sense of the word, therefore, becomes the basic cause of wind resistance of the individual tree, and it may be appropriate briefly to consider some of the well-known characteristics of certain soils as far as their potential rooting possibilities are concerned (7, 8, 26, 28, 32, 41, 53).

The most important point is the soil texture. This factor determines not only the rooting depth and the lateral extension directly by its mechanical influence, but also through its far-reaching effect on the moisture conditions. The most favourable physical conditions are found in coarse-textured soils, on dunes, alluvial sands and gravels, and glacial deposits poor in clay, that is on sites with a uniformly large pore space, free drainage, and no pronounced compacted horizons. If the moisture conditions are favourable these soils allow all species an extensive vertical root development and a large total root mass, and accordingly there is little difference between the wind-firmness of species. On morainic soils with a larger content of small-size particles and more or less stony, root extension will decline even under conditions of free drainage, but in such a way that the deep-rooting species will possess an increasing advantage (32). Where there are soil horizons that limit root penetration, the difference between the type of reaction of different tree species becomes conspicuous. Such may be either a heavy clay with an unfavourable balance between water and oxygen, or a loamy moraine, where clay particles are deposited in a pan-like formation. Spruce and Douglas fir (*Pseudotsuga taxifolia* Brit.) roots are almost unable to penetrate a compacted layer and are very scarce in a dry, leached horizon; on heavy soils the root systems are flat and superficial. Pine and larch go deeper and although their roots are unevenly distributed several of them penetrate through fissures and cracks, and along old root channels, into or through dense, compacted layers. In the case of larch it has been shown (28) that there exists a correlation between the size distribution of soil particles and root development: typical heart-roots reach an average depth of 4–4½ feet in fine sand very poor in clay; 'horn-roots' (systems with single vertical roots) reach 3 feet in a silty moraine rich in fissures, and flat-roots only extend to 16 inches in a mixed moraine with a very low pore space.

In the part of Scotland affected by the recent gale an unfavourable physical constitution of the soil has a widespread and direct effect. For the country as a

whole, however, the root development mainly depends on the water régime in the soil, as it is expressed in a high water table, intermittent water-logging, and formations of raw humus and peat. The problems arising in conjunction with the natural and artificial drainage and their relation to gale risk are fully treated by Day (11) and Petrie (40). A deep peat layer causes for all species a pronounced superficial rooting and an accordingly large risk of wind-throw. On less peaty sites there is some difference, spruce exclusively rooting in the humus layer, while Scots pine roots go down, brush-shaped, to the water table. Impeded drainage is in all respects a factor, which severely affects the stability of a tree crop, even if it does not influence the rate of growth.

On shallow mineral soils and accordingly with limited root space in the vertical direction, the shallow rooting species possess a certain ability to adapt themselves to the wind climate by increased growth of the horizontal supporting roots (20). Thicker lateral roots to the leeward side of the stem improves the resistance against root-bending and root-breaking, which is part of the act of wind-throw. This increase is presumably caused by a physiological reaction to wind-pressure and is correlated to the force and direction of the prevailing winds (20, 32, 38).

Evidence from the storm in Scotland, 31st January 1953

The region that suffered severe damage during the recent gale is underlain by rocks mainly of granite, gneiss, different schists, and Old Red Sandstone. The soil types are, however, mainly dependent on glacial drifts of varying age and depth. The range in fertility is great, and the soil texture changes rapidly from place to place. Elevation, aspect, and precipitation play an important part in the formation of rooting possibilities apart from the type of parent material.

The relative number of broken stems indicates to some extent the degree of root resistance and there is a fairly good correlation between the percentage of broken trees and rooting depth. Stands of Scots pine where breakage exceeds 25 per cent. are all young stands on deep freely drained soils; approximately 10 per cent. is found in older stands on the same type of soil and in younger stands on shallower mineral soil, while uprooting is almost universal in old Scots pine on soils with impeded root development as well as in all species and age classes on peaty or waterlogged soil.

Adverse moisture conditions are of widespread, but local significance. Woodlands on deep peat are uncommon in this region, and it is unusual to find trees, whose roots are wholly confined to the humus layer. The most common feature is a water table less than a foot below the ground, which in many cases seems to be directly caused by a heavy loam texture, impeding local drainage. On these soils, spruce roots, and generally also beech roots, spread horizontally, while a large number of small pine roots extend vertically some inches into the periodically water-saturated horizon. Accordingly, the gale damage is usually severe, and although only small areas suffer from the more pronounced types of waterlogging, they have acted, and may be expected in the future to act, as centres for the spreading of further gale damage.

Of more general occurrence in the region is a mechanical shallowness of the

soil caused by an induration of a horizon, which may lie from 1 to 3 feet below the surface. This, at times forming a completely cemented layer, is generally several inches thick, merging gradually into the subsoil and representing a serious obstacle to root development. It is common on the relatively light-textured, freely drained loams of granitic origin in Aberdeenshire. An analysis of pore space of a soil profile with a typical indurated layer has been made by Dr. T. W. Wright, Macaulay Institute. The soil samples were taken from a pine wood, approximately 60 years old, on a gentle north slope a few miles west of Aberdeen. The soil is a freely drained, coarse sandy loam, which shows a decrease in pore space from more than 50 per cent. in the top of the mineral soil to 20–25 per cent. at a depth of 2–2½ feet. The roots of the blown trees are seen to form a profusely branched, flattened system immediately above the compacted layer. The difference in porosity of the soils from the blown and the unblown parts of the wood are not striking although the induration in the latter case lies somewhat deeper and immediately below a pronounced porous layer (pore space 40–45 per cent.). It is likely that several local variations in the severity of the gale damage are caused by differences in available root space.

Depth, extension, and hardness of the compacted layer are not reflected in ground vegetation or tree growth, and its occurrence is silviculturally of interest mainly from the point of view of wind resistance, that is how far certain species can ultimately penetrate this unfavourable horizon. Oak (*Quercus* spp.) and particularly Scots pine are frequently seen to send out wedge-formed roots, reaching 10–12 inches below the general root level, and it may be assumed that the deep-rooting species on medium compacted soils have a real advantage compared with shallow-rooted. In a mixed stand of Douglas fir and Scots pine on a site where the density of the soil gradually increased downwards, the average rooting depth was found to be 22 inches and 34 inches respectively. In this case, where the general exposure was severe, there was apparently no difference between the species as regards wind resistance.

The feature previously mentioned, namely, shallower rooting species compensating to some extent for lack in depth by increased growth of the horizontal roots, is observed in most instances where pine and spruce occur together; in one case it was found, for instance, that the root spread of the pine was 8 feet against 11½ feet for spruce. As an increased development of the horizontal roots is likely to be reflected in the degree of root swelling at the base of the stem a comparison of this factor was made between standing and fallen trees in several, partly blown stands: 20 to 30 trees with approximately equally developed crowns were selected; the girth was measured at 1 foot and 4 feet 3 inches from the ground, and the relative butt swelling was determined from the quotient of the upper and lower measurements. These showed that the difference in root swelling between the fallen and standing trees was small, namely, about 5 per cent. less swelling in the fallen trees. In six cases out of eight the difference, however, was statistically significant. The important point, however, is that the difference is small and not detectable visually. It is accordingly not possible to recognize a presumably more resistant root system above the soil surface. It must, however, be mentioned that

all measurements were taken in larch and pine stands, and that better results might be obtained with spruce. Further examinations of root systems have also given negative results. There is no detectable difference between the large surface roots of standing and of blown trees. Neither has it been possible to observe any effects of the prevailing wind on strength and extension of the horizontal roots.

It may generally be concluded that the large variation in rooting habit which the January gale revealed, is an important factor in establishing different degrees of wind resistance, but this effect was largely obliterated by the extreme force of the gale. As far as the Scots pine is concerned it is the depth of the root system which is important, and most likely this is true for other species too. As the rooting depth depends on soil properties it is important to investigate how far these can be improved by cultural methods.

TREE SPECIES

General views

The characteristic wind resistance of the species commonly employed in forestry is fairly well agreed upon and well known from general experience. In accordance with the opinions expressed in most textbooks on silviculture, one can prepare a 'gale firmness series'. The conifers on one hand and the broadleaved species on the other constitute two groups, which are not easily comparable. The series in decreasing degrees of resistance are as follows. Conifers: European larch (*Larix decidua* Mill), Scots pine, Silver fir, Norway spruce, and Douglas fir. Broadleaved: oak, sycamore (*Acer pseudoplatanus* L.), ash (*Fraxinus excelsior* L.), beech (*Fagus sylvatica* L.), and birch (*Betula* spp.). The properties of species belonging to the same genus are approximately similar.

Quantitative assessments of resistance have not usually been attempted, comparisons being based on impressions and visual estimates alone. This must be explained by the fact that different species neither in growth nor in development of wind resistance do react uniformly. For example, season plays an important part. During the summer at least the pines are equal in resistance to most broadleaved species (15) while during the stormy season from October to April only the deciduous larch is comparable with these. Equally important are soil conditions, age, and also the actual gale force. It must, therefore, be expected that the effects of a given gale in a particular region will show distinct deviations from the average.

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It is important, therefore, to record the species resistance in this gale, although the wind speeds were so high that in many cases specific differences were obliterated, and in addition, there is the complicated pattern of soil and rooting habit in the region, which occasionally has favoured the deep-rooting species and in other places been a relative disadvantage to them. It is important to note, also, that Scots pine and broadleaved species are predominant in the older age-classes and spruce is only to be found in young plantations. The results are, therefore, not generally suitable for an estimate of specific resistance. It can, however, be stated

that under the wind speeds recorded no species, broadleaved or coniferous, proved entirely wind-firm.

As no detailed statistics of blown timber in relation to the standing volume is available, a comparison must be based on indirect estimates. According to the 1947–9 Census of Woodlands (18) the amount of broadleaved species above 60 years in proportion to conifers over 40 years is approximately as one to six, taking the area proportions of Aberdeenshire as a basis. The ages 60 and 40 years respectively are considered to be the average minimum ages for risk of severe wind-throw. This ratio corresponds well with the official estimate that the total loss of about 45 million cubic feet consists of 85 per cent. softwood and 15 per cent. hardwood (46), and confirms the general impression that the broadleaved woodlands have suffered equally severely.

Scots pine is the predominant conifer in the region affected. Taking into account the differences in topography and soil on which it has been established, it is not surprising that it has not reacted uniformly, but in view of the fact that it is generally considered a wind-firm species, its behaviour in the January gale is discouraging. Large areas of Scots pine have been flattened, which is usually only the case with shallow-rooting species. Given optimal sites, that is, where its deep-rooting ability is unrestricted, the Scots pine has on an average been more wind-firm than some other species, but much less than has previously been believed. Larch has on an average proved resistant to wind-throw. The small exposed crown surface in its leafless condition and the flexibility of the stem have been important factors. It has been observed repeatedly how the gale has picked out more Scots pine than larch, where the two species were in mixture. No difference between species of larch has been observed. Spruce plantations in the dangerous age-classes are, as previously mentioned, not common in the region devastated by the storm. As they are usually planted on wetter sites, soil conditions add to the risk of wind-throw caused by a shallow root system. It is, therefore, of special interest to observe instances, where spruce is not more severely damaged than pine on similar sites. This occurs and must modify the statement that spruce is an unstable species under all conditions. It is of interest to note that Norway spruce proved wind-firm in the same region of Scotland in the severe gale in 1927. Unfortunately the Silver fir is uncommon in north-east Scotland apart from single trees in policy woods, &c.; its reputed ability to penetrate compacted soils might be of value in regions where this limiting factor is present. The individual old trees have often stood up well, and were not inferior to Scots pine in this respect, but the tops were occasionally broken.

The wind resistance of other exotic species is difficult to assess due to lack of material. Several of the north-west American conifers have proved to be gale-firm when occurring singly or in groups. The January gale has at least not supplied evidence that undue risk of gale damage should prevent the use of these species. The case of the Douglas fir is of especial interest. It has previously been considered a most unstable species, and did prove to be so in the gale of 1927. In the last gale it has, however, in several instances been wind-firm to a surprising degree. The conspicuous difference in behaviour in different localities seems mainly to depend

on soil conditions, to which Douglas fir is even more sensitive than Norway spruce; light textured, porous soils being essential for its proper root development.

Among the broadleaved species, beech has the same predominant place as Scots pine as a tree of the region. It has on an average been very badly damaged, although the throws are generally more irregular and scattered than in the pine, often forming wedges in the direction of the wind. Many of the serious losses in beech must be attributed to age, a large proportion of stands having passed maturity. Of other broadleaved species represented in Scotland the oak and the sycamore have generally been more resistant than beech; birch and ash probably a little less. Even the oak, however, has suffered serious wind-throw over considerable areas.

AGE OF STANDS

Review of literature

The increase in gale damage with an increasing age of a stand is repeatedly mentioned in the literature. Usually this is considered a matter of course and briefly explained as the result of a larger resistance of young stands against uprooting or breaking. Theoretically, two reasons for this may exist. The first is the increase of wind speed with height above ground; this increase follows approximately a logarithmic curve and results in a considerably larger wind-pressure per unit of crown area of a tall tree. If the proportions between different parts of the tree do not change with increasing height growth, it must necessarily be the only explanation. It is, however, not likely that this increased pressure is of sufficient magnitude to represent more than a contributing factor. The other possibility is that there is a definite difference between small trees and large trees as regards the relative proportions of crown and root mass, which determine the resistance/pressure ratio. The stress on the root system, transferred from the wind-pressure on the crown, increases rapidly with height of tree, and investigations have proved (8, 32) that the relative size of the root mass becomes smaller as trees grow larger. In addition some importance must be placed on the change of form factor with increasing height growth. Moreover, the relatively large height/diameter ratio in young trees involves a larger bending at a given pressure per unit of crown area; in that way young stands can, by movements of the stems, absorb a large part of the wind-pressure, without transferring it into a cantilever effect upon the root system.

A few studies of wind-blows give some figures for the relative stability of different age-classes. Based on a fairly large number of observations from a summer gale in Germany (15), the relative gale firmness for beech was shown to decrease from unity for very young stands to about 0·7 at 60 years and 0·3 at 100 years. This decline was slower for the deep-rooting oak and pine, but much more rapid for spruce. A gale in Denmark on 11 February 1952 was of the same type as the Scottish January storm 1953, as regards speed, direction, and duration, and left a similar pattern (31). The largest proportion of the damage took place in Norway spruce (9 million cubic feet). Young stands of this species, 0–25 years, were undamaged, 12 per cent. of the wind-throw occurred in middle-aged stands

between 25 and 50 years of age, and 70 per cent. in old stands, while areas in the process of regeneration accounted for 18 per cent. Other conifers behaved in the same way, and wind-throw among broadleaved species was limited to the oldest age-classes, 100 years and more.

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The correlation between tree height and damage suffered is one of the most conspicuous features in the pattern left by this storm. Although complete data are not available, the distribution of damage has been estimated, based mainly upon measurements in Scots pine stands. Up to a height of 30 feet, wind-blow is scarcely ever seen. It is still infrequent in the 30–40 feet class, and is here mainly confined to sites which are very exposed or with adverse soil conditions. It is interesting to note, that where damage occurs in young stands on freely drained soils it tends to appear as breaking, suggesting a high degree of root resistance, which agrees with the theory already mentioned. At heights greater than 45 feet a rapid increase in damage takes place. Few exposed stands above this height have stood up completely and the wind-blow is often more or less complete. This danger limit is somewhat higher in the less exposed upper valleys; it depends probably on the actual force of the wind. Above approximately 50 feet it is difficult to ascertain any relative increase in damage. There is no striking difference between the 60 and 80 feet classes of Scots pine; the extent of the blow presumably depending mainly on other factors. But in broadleaved species and larch, damage continues to increase with height and age.

The influence of age explains why Forestry Commission woodlands have suffered relatively little, 7–8 per cent. of the total damage, the remainder being in private woodlands.

LAYOUT AND STRUCTURE OF FORESTS

Review of literature

Forests are obstacles against wind movement comparable with physiographical objects, and they correspondingly influence the wind-field above and around themselves in such a way that the horizontal and vertical shape of the forest is of immediate importance for the potential danger of wind-throw. The man-determined construction of the forest is especially significant at the margins and in the interior arrangements of species and age-classes.

The effect of forest margins is recognized in theory as well as in silvicultural practice (see, for instance, 16, 20, 27, 39, 49, 51, 54, and 56), and they are generally regarded as an important factor in prevention of gale damage.

The first consideration is the shape of the boundary of the forest. If this is not a straight line, weak points tend to occur wherever acute angles form a funnel into the wood (44, 54). In addition to the shape or outline there is the effect of its vertical profile. Its function is a double one (51): it gives direct shelter to the stand behind, and it provides a barrier to the spread of gale damage. Without any human interference the trees along the edge of the forest will develop naturally

in such a way that a more resistant margin is formed. The roots of marginal trees grow more vigorously and develop greater supporting strength than do those of trees in the closed stand, the stem form becomes less cylindrical, and in particular the height of the trees decrease from the interior towards the border (20, 30, 38). These morphological changes depend chiefly on the exposure and contribute to the gale resistance of the margin. The slow and smooth transition from field to forest produced by the sloping canopy probably also involves less turbulence and accordingly less danger of wind damage at some distance from the edge (20).

The marginal trees only yield shelter from the horizontal component of the wind; in so far as there is a vertical component, this together with the turbulence effect of the crowns may increase damage in the interior (51). This is a serious limitation to the beneficial effects of the margin. An artificial production of a sloping canopy by top-cutting the edge trees is claimed to have given good results (10). As the profile type depends on the exposure some difference is found between different aspects of a forest, the aspect facing the direction of the prevailing wind being best adapted to wind resistance. The most important effect is, however, the species used. Most of the broadleaved species, and particularly beech whose crown is very sensitive to exposure, produces a margin which gradually rises in height, while it is relatively wind-firm. The pine reacts less favourably and the spruce only very little (38). The silvicultural treatment of the margins aims at stabilizing their wind-braking influence, which extends to about 2–3 times the mean height of the margin trees (51).

The stability of margins depends on the degree of thinning. A very heavy thinning, spacing the individual trees so widely that their crown percentage is approximately 100, seems to ensure a fairly high degree of resistance, particularly when supplemented by underplanting (55, 56, 57). It is maintained that the depth of the treated margin must be about 100–150 feet, not in order to increase the sheltering effect, but to make sure that an accidental loss of a few trees does not endanger it (57). A single row of wind-firm trees is a minor advantage; wind damage occurs regularly even if one tree is blown at intervals or there are wide distances between the trees.

An interior system of wind-firm strips does not develop naturally. It is, however, necessary in regions exposed to gales and must be planned and treated from a very early age. Following natural boundaries, they should enclose units of 5–10 acres, protecting them individually; when properly designed they have in the past proved satisfactory and an important factor in protection (27, 51, 57).

Effect of structure of the forest is controversial. It is mainly the question of whether an increase in irregularity, or unevenageness, is an advantage from the point of view of gale danger. Most authors on the continent agree that woodlands managed according to a strict Selection System are less liable to suffer from gales than regular high forests (9, 12, 27, 29, 51, and 57). On the other hand, it is not proved, and it seems on the whole unlikely that irregularity under all circumstances is an advantage. Investigations have shown (55) that single trees, groups of trees, and stands that reach above an otherwise uniform canopy are apt to be damaged by wind. Similarly, a mixture including a wind-firm species and under-

planting are generally useful measures, but a few scattered wind-firm trees in a stand of a less-stable species may have an unfavourable effect (55), establishing an irregular wind field with locally increased speeds and wind-throw in their immediate neighbourhood (55). It is, accordingly, not possible to forecast how group planting developed by Anderson (3) will behave in gales. In due course, the reaction of this method will be interesting.

It seems unquestionable that any stand, independent of its size and its uniformity, is relatively stable against moderate gales, as long as it is normally stocked (55). The danger arises when for some reason it is opened up and an otherwise sheltered edge is exposed, for example, by beginning regeneration operations or by a break in the canopy caused by some insect or fungal attack. When this happens, the spreading of wind-throw becomes almost inevitable. For this reason small stands, not over 10 acres, are considered an advantage (27, 57).

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The effect of the structure and layout of forests on type and degree of gale damage has in this case not been obvious; the wind speeds were such that their effects were obscured.

It has not been possible, for example, to decide if some degree of irregularity has had any effect on the damage suffered, because deviations from the normal type of regular forest are few and not suited for comparisons. In several instances it has, however, been verified that a stand rising above an otherwise level canopy is very liable to blow. Apparently no partial shelter effect is produced by a lower stand to windward, but on the contrary an increase in wind speed or gustiness takes place immediately above its crowns. On the other hand, it is interesting to note in several policy woods that single trees, 15 to 20 feet taller than the average height of the stand, are the only survivors; a larger wind firmness, developed during many years of free exposure, seems to have been adequate to resist very considerable wind pressures.

The influence on wind resistance caused by continued exposure to open-land wind velocities is also obvious from the fact that forest margins are considerably less damaged than the interior of the stands. This feature is particularly notable at the south-west margins, which often have been left in a narrow strip, while the rest of the stand is flattened. This is probably due partly to a decrease in tree height, which is particularly large along the edge facing the prevailing wind, but also to a root development causing a more favourable relation between wind-pressure and mechanical resistance. The exposure may be considered to be determined by the long-term frequency and speed of wind from different directions. It is possible to get an estimate of the 'wind energy' acting on a certain margin by multiplying for this direction the wind-pressure corresponding to each speed with its frequency and adding these products. Wind-pressure is assumed to be equal to the square of the wind velocity in m.p.h. Detailed figures of wind speeds and frequencies have been supplied for Aberdeen (Girdleness Lighthouse) for the period 1947–52. A calculation based on these show that approximately 50 per cent. of the total 'wind energy' is concentrated at south and

south-west directions, indicating that these margins were more exposed and also better adapted to wind than those facing north and east.

There seems to exist, therefore, a close correlation between general exposure and wind-firmness. This relationship is also reflected in the difference in damage between woods of different size. Making due allowance for the large number of old and weakened individuals amongst the single trees, hedgerows, and small woods in the area concerned, gale damage is on an average less in small woodlands, a feature which is probably determined by a larger relative margin effect. The importance of the edges can be traced in several other instances. It is, for instance, notable how power lines and war-time fellings producing non-adapted edges have contributed to an increase in damage.

On the whole previous experience concerning the effect of the layout of margins has been verified. In a number of cases funnel effects have been observed, taking place where the wind met an acute angle or became linked in some other way; protruding parts are often undamaged. The construction of the edge has also played a part. The common practice of planting one or a few rows of beech along the edge has usually had a favourable influence for at least 50–100 feet. This observation must be qualified, however, by instances where stands behind a few widely spaced broadleaved trees show wedge-formed blows, either between the trees or where a tree has fallen. This stresses the point that a sheltering margin needs a depth of probably 100–150 feet to become an effective protection.

THE INFLUENCE OF TENDING AND REGENERATION TECHNIQUES

Review of literature

The relation between silvicultural treatment and gale damage has received much attention and has led to different views. This is particularly the case as regards the question of whether heavy thinning increases or reduces the risk.

A thinning can under certain conditions improve the average wind resistance of a stand by removing trees suffering from root diseases (31), but otherwise it cannot be assumed (53) that any usual kind or degree of thinning does favour the more wind-firm individuals. Whatever the type of thinning, root and crown competition are reduced, which on the one hand involves an increased exposure of the individual trees, and on the other the possibility of developing a more resistant root system. Recently thinned stands are, therefore, generally more liable to blow than stands which have not been touched for some time (21, 31, 53). There appears, however, to be exceptions to this rule (10). Most convincing of observations regarding the relationship between the degree of thinning and wind resistance are the results obtained from the Prussian experimental thinning plots (53). In none of the series has the heavily thinned plots proved more wind-firm than the lightly thinned, but have generally suffered more. Also in Denmark some thinning investigations have been brought to an end because of wind damage in the heavily thinned plots. The more recent observations from Middle Europe, Prussia, Bavaria, Bohemia, and Switzerland (9, 20, 27, 53, 55) indicate that the effect of thinning on wind resistance of a stand is a secondary one, and is not a reliable means of preventing gale damage. This agrees with general experience

in other forest types, for example in the Scandinavian countries. Most resistant are forest margins, which during a long period have become adapted to exposure to wind, particularly if they have been heavily and continuously thinned. This is also true for edges along roads and fire-lines; in this case the heavy thinning is certainly a favourable measure, and is one means of developing interior wind-firm strips mentioned in the previous section. Nevertheless an efficient improvement of the gale resistance of a stand by means of the treatment must usually take place in other ways, by mixture with wind-firm species (27, 52, 55), by underplanting (55, 57), and, mainly, by creating a system of wind resistant margins. Possibly some advantages are gained by using wide initial spacing (26). The chief advantage of a medium to heavy thinning lies in the fact that it makes it possible to keep stands under control and remove weakened trees before they are actually blown down.

Preparations for regeneration imply a more or less abrupt encroachment upon otherwise closed stands and accordingly cause a considerable increase of the risk of wind-throw. It is not possible to avoid this risk completely, not even by using the most careful procedure. The forest areas in Scotland which will become due for regeneration in the near future are, however, so few that it is probably premature to discuss questions of method in detail, although gale risk inevitably is going to become a serious and decisive factor. It may be appropriate only to mention the relatively favourable results which have been obtained in Middle Europe (20, 49, 52) by orientating the regeneration coupes against the prevailing wind direction, and separating cutting sections by severance cuttings. Supporters of a slow group regeneration beginning in the interior of the stand, which is becoming more and more common, claim similar and greater advantages for this method, but so far the evidence is scanty. On the other hand, it is well known how rapidly the risk of wind-throw is increased if an abrupt reduction of number of stems takes place. Thus the Uniform Shelter-wood System may prove unsuitable for all except the most sheltered sites in Scotland.

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The only quantitative estimate of the degree of thinning which can easily be determined is the approximate average spacing. A comparison on this basis demands, however, that the stands are separated according to species, exposure, and soils. A fairly comparable set of material, consisting of 21 stands of Scots pine of different age-classes, on medium exposure sites, and on freely drained mineral soils, has been analysed. The normal density for well-thinned Scots pine stands, as measured by the ratio Top Height/Average spacing, should be about 20–22 per cent. (19). In the sample analysed, however, there is a wide range of density, so determined, but no correlation between this factor and the degree of damage could be detected.

More information can be drawn from the permanent sample plots of the Forestry Commission. Of 14 severely damaged plots 3 belong to B-grade, 10 to C-, D- and C/D-grades and 1 to L/C-grade. Apart from the more frequent occurrence of heavier thinning grades and small random differences in exposure

the tendency is for a reduced resistance with increased thinning. A comparison between estates with different thinning régimes is impossible, but there are at least no striking differences in damage, correlated with tending.

On the whole it is apparent that there is no close relation between different kinds or different degrees of thinning and the damage suffered. Only in very few cases has thinning had any effect at all. One instance is the very inadequate gale resistance of recently thinned stands, which verifies previous experience. In comparison with these stands it is interesting to observe how occasionally very densely stocked, almost untouched, pine and larch woodlands have survived undamaged. Rather heavy, regular thinnings seem, however, to have caused less complete wind-throw in some instances, the damage taking place being more scattered. This may not be the general rule, but is quite comprehensible in view of earlier experience.

In pine forests it is remarkable that the survivors in the severely blown woodlands are the most slender, whippy individuals which would normally be removed in thinning. Similarly it has been observed in some young spruce plantations that the gale has regularly blown the largest and most full-crowned trees. In cases where the damage is more sporadic it is, however, not possible to show any significant difference in crown development between the blown and the still-standing trees.

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Appendix I

Previous Gales, affecting Scottish Forests

Year and Month	*Region*	*Meteorological data*	*Damage on forests*	*Source*
1952/Jan. 1951/Dec.	N. and NW. Scotland	SW. to NW. Gusts 108 m.p.h. at Clydeside and Hebrides.	0·3 mill. cbf. on F.C. woodland 4 „ „ private „	*Forestry Commission Journal*, 1952.
1937/Feb.	NW. Britain.	NE. Mean velocity 64 m.p.h. and gusts 107 m.p.h. recorded.	Severe damage reported from Kielder Forest. Apparently not serious north of the Border.	*Forestry Commission Journal*, 1938.
1927/Jan.	Mid and W. Scotland.	S. to SW. Gusts above 100 m.p.h. at Glasgow and Hebrides. Gale force outstanding for period 1900–35.	Damage known to be locally severe; considerable in Tay and Dee valleys. Especially Douglas fir suffered.	*Quarterly Journal Royal Meteorological Society*, 1931. *Forestry Commission Journal*, 1928.
1911/Nov. 1912/Dec.	Probably local: Central Scotland.	Direction SW. to W. Maximum gusts recorded: 90 and 81 m.p.h.	The two gales apparently belong together, as the effect of the latter was increased by gaps created by the first. In all almost 100,000 trees were blown on the Perthshire Estates, mainly in the 40–80 years age-class of Scots Pine.	Mr. Frank Scott, Private communication.
1894/Dec.	Central and S. Scotland (N. England and Ireland).	SW. to N. Hourly averages about 60 m.p.h. on east coast, above 100 m.p.h. on west. Strong gusts. Before 1900 records of wind speed (Robinson Cup Anemometer) not quite comparable to later records.	Severe damage reported from Argyll, Arran (40,000 trees), Kirkcudbright, Perth. (It is mentioned that the damage was less than might have been expected because the number of exposed woodlands had been much reduced in previous devastating gales.)	*Quarterly Journal Royal Meteorological Society*, 1895. Sir Herbert Maxwell, *Memories of the Months*, 1st ser. 1931. W. R. Fisher in Schlich's, *Manual of Forestry*, vol. iv.

Appendix I—*Previous Gales, affecting Scottish Forests*

Year and Month	*Region*	*Meteorological data*	*Damage on forests*	*Source*
1893/Nov.	Most of Scotland; part of England and Ireland.	Mainly NW. to NE., but very variable. Storm of several days duration. Wind records show 80 to 100 m.p.h. in west and north, but only about 50 m.p.h. in most of Scotland.	Sutherland: More than 50,000 trees blown down; Perthshire and Forfar: estimated 1·85 mill. trees (e.g. Blair Atholl, Killiecrankie). Less damage towards east.	*Quarterly Journal Royal Meteorological Society*, 1894. Fisher in Schlich's, *Manual of Forestry*, vol. iv.
1884/Jan.	Scotland, mainly south.	Direction varying locally. Maximum hourly average: Northumberland: 76 m.p.h. Glasgow and Aberdeen: 50 to 60 m.p.h.	Considerable damage, mainly in SW. One estate estimates a loss of 1 mill. trees. Structural damage during the stormy period 19th to 31st January stated as general.	*Quarterly Journal Royal Meteorological Society*, 1894. *Meteorological Magazine*, 1884.
1883/Dec.	S. and W. Scotland.	No meteorological data available.	Damage recorded from Dumfries ('thousands of acres of plantations blown'), Roxburgh and Argyll. No damage in E. and N. Scotland.	*Meteorological Magazine*, 1884.
1882/Jan.		Direction W. Hourly maximum wind speed recorded 82 m.p.h.	20,000 trees blown at the Atholl Estates.	*Chronicles of the Atholl and Tullibardine Families; Edinburgh* 1908 vol. iv. *Q.J.R.M.S.*, 1894.
1881/Oct.	Mainly south and central; general over Britain.	W. to NE. in the areas most affected. Beaufort force 11 recorded at most stations in U.K. Very gusty.	Enormous devastations reported for S. Scotland: Roxburgh, Berwick, Haddington ('whole acres of oaks, beeches and elms are blown down'), Perth and Fife. Not serious north of Aberdeen.	*Q.J.M.S.*, 1882, 1903. *The Journal of Forestry*, 1881.

1879/Dec.	Scotland, south of Caledonian Canal.	Direction SW. to W. Hourly maximum wind speeds are relatively small, but very strong gusts. (The Tay Bridge Storm.)	Damage to trees from Argyll to Aberdeen. (Braemar: thousands of trees uprooted.) Central districts and Highlands mainly affected: whole woods of Scots pine blown down in Glen Lyon; serious damage to broadleaved woodlands along Tay.	*Meteorological Magazine*, 1830. *Q.J.M.S.*, 1880. *Journal Scottish Meteorological Society*, 1880.
1868/Jan.	S. Scotland.	Southerly, accompanied by rain and snow.	Some damage in the southern counties.	*Meteorological Magazine*, 1868.
1860/Oct.	N. Scotland.	Direction NW. lasting for a few hours. Beaufort strength 12 reported from the region.	Severe structural damage and local wind-blows in forests reported.	*Comm. Royal Observatory, Edinburgh*, 1871.
	(A few gales are reported from the middle century. They seem to have had a more local character and in no case has information been found of damage to woodlands.)			
1838/Nov.	S. Scotland touched; severe over England and Ireland.	Direction S. to SW.	General damage to forests in England, only local in Scotland.	*Transactions of the Royal Society of Edinburgh*, 1839.

Before this date the following gales are known to have affected Scotland:

1838/Nov: Severe damage.
1826/Nov: Several thousand trees blown on the Atholl Estate.
1739/Nov: Steeple of St. Giles Cathedral, Edinburgh, damaged.
1703/Nov: Probably the most famous gale in Britain: Eddystone lighthouse destroyed, structural damage estimated at £2 million; devastation of forests. (Kent: 17,000 trees blown.) Described by Daniel Defoe.
1694/Oct: The disastrous sand-storm at Culbin, Moray Firth.

Appendix II

Actual cases of wind-throw, illustrating statements in text

The largest part of the gale damage, which occurred on the 31st January 1953 cannot be attributed to any single factor. The velocity and the duration of the storm obliterated most of the effects of what may be called the minor factor complex, which on a lower level of gale force might have been the deciding elements. Accordingly it is difficult to assess the relative value of these factors in the actual cases and to discover where one or the other has had a determining influence. The following notes are intended to suggest how deviations from the normal picture may arise. (National grid references given.)

Topographical causes

On exposed slopes: (1) Ballogie estate (45/595980). A moderate N.-NE. slope; uniform, almost pure Scots pine, 60 feet, average stocking. A typical example on a large scale of the complete flattening of an exposed slope. The wind-throw is approximately limited by the contour of the summit.

(2) Ballindalloch Estate (39/170355). A steep N. slope, stocking like (1), but a considerable proportion of larch. A case where larger wind resistance of the crop probably in conjunction with less severe gusts has confined the blow to the middle slope, mainly under the 1,000 feet contour.

(3) Forestry Commission, Monaughty Forest, Morayshire (28/140590). A wide variety of coniferous species on a moderate N. slope. Height of trees varying (40–50 feet). The forest is generally wind-firm, because it is young. The wind-throw is scattered and has mainly taken place on the lower slopes, where gleying occurs and the root-hold is reduced.

On sheltered slopes: (4) Glen Tanar Estate (44/470950). Steep S.-SE. slope, Scots pine, 60 feet. The typical case: The sheltered slope is almost undamaged, while the throw is severe to complete on the N.-facing aspect, which carries a similar crop.

(5) Crathes castle (45/740973). A gentle S. slope with a mature crop of mixed broad-leaved and coniferous forest. The shelter afforded by the slope has not been adequate, and the wind-throw is complete.

(6) Learney Estate (45/645050). A moderately steep S. slope, Scots pine 35 feet, approximately situated 100 yards below the heather covered summit. One of the few cases where a windfirm stand in a sheltered position has blown, probably caused by turbulence to the lee of the hill-top.

Effects of margins and structure.

Angle: (7) Forglen Estate (30/705501). Gentle S. slope with mixed Scots pine and broad-leaved, mature. A small wedge-shaped wind-throw has taken place on the point of the forest margin, where this changes from an E.-W. direction to a N.-S.

Funnel: (8) Learney Estate (45/651058). Scots pine and Norway spruce, 40 feet east of the main road. A narrow wedge has been blown opposite a road joining the main road from west.

Non-adapted edge: (9) Dunecht Estate (45/777054). 60-year old Scots pine on almost flat ground. The degree of damage is increased south of open strip cut for power line.

Marginal belt, effective: (10) Durris (45/810954). Gentle NW. slope; Japanese larch, 40 feet, exposed to north. There is one row of young beech to this direction. It has afforded shelter approximately 25 yards into the stand, after which 50 per cent. of the trees are blown.

Marginal belt, not effective. (11) (45/780150). Wood-land south of main road, consisting of middle aged Scots pine. At the roadside a row of old beech, spacing varying 40–80 feet. Wind-throw in Scots pine has taken place either where a tree in the margin has fallen or in the interval between two beeches.

Height-differences, stands: (12) Forestry Commission, Dalliefour (44/346964) Scots pine, 55 feet on NW. slope. Among the neighbouring stands to NW. is a young stand of Scots pine (35 feet). Damage has taken place behind this.

Height-differences, trees: (13) Forestry Commission, Kirkhill (45/345964). Sitka spruce on moist site, 40–45 feet tall with considerable differences between trees. The largest individuals have regularly blown.

OBSERVATIONS ON CONE AND SEED PRODUCTION IN PLANTATIONS OF SCOTS PINE IN SCOTLAND

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SUMMARY

THE results of investigations carried out over a period of five years (1948–52) in a typical stand of planted Scots pine (*Pinus sylvestris* L.) in Aberdeenshire are presented. A marked fluctuation in cone production per tree during the period was observed. An examination of the meteorological data suggests a possible correlation between cone production and the temperature conditions at the time of flowering. The number of seeds per cone varies within wide limits. Marked variation in cone type was observed, but without a systematic classification of cone types for the species it is not possible to connect type with productivity. A significant relationship between dominance and both cone and seed production was established. A comparison between visual estimates and actual counts of cone crops revealed that a high degree of accuracy can be obtained by visual estimate.

INTRODUCTION

As part of the comprehensive study of the natural regeneration of Scots pine in Great Britain it is desirable to have more complete and more definite information than we possess regarding the numbers of cones and seeds which are produced annually by this species. It is well known that the numbers of cones which mature vary from year to year and a periodicity of cone production is considered to occur. This is reflected in so-called good cone or seed years which are usually stated by various authorities as appearing on the average every third or fourth year. Apart from this rather general knowledge little is known about the seed production of this most important native conifer.

The objects of the observations recorded in this note were to obtain definite figures regarding cone and seed production of Scots pine over a period of years and, if possible, to discover what factors influence this production.

Almost all the Scots pine in this country has been artificially planted and natural regeneration methods if ever employed will have to be applied to stands of such origin. A sample of what may be considered a fair average of such Scottish plantations was selected for observation over a period of 5 years from 1948 to 1952 inclusive. Specific questions were set to be answered; these in brief may be stated as follows:

1. How many (*a*) cones and (*b*) seeds are produced annually per tree in plantation grown Scots pine?
2. What relationship is there between (*a*) dominance and (*b*) crown form of the seed bearers and cone and seed production?

3. How far does cone type vary and is there any correlation between cone type and numbers of seeds?
4. Can any clear connexions be established between the occurrence of seed years and meteorological records?
5. What degree of accuracy can be placed on visual estimates of numbers of cones?

LOCATION AND DESCRIPTION OF THE SITE

The following is a brief description of the location of the plantation examined and the site factors obtaining.

Situation. Dalliefour Wood, Alltcailleach Forest, Near Ballater, Aberdeenshire. National Grid Reference 38/353965.

Altitude and slope. 500–600 feet above sea level. Practically flat.

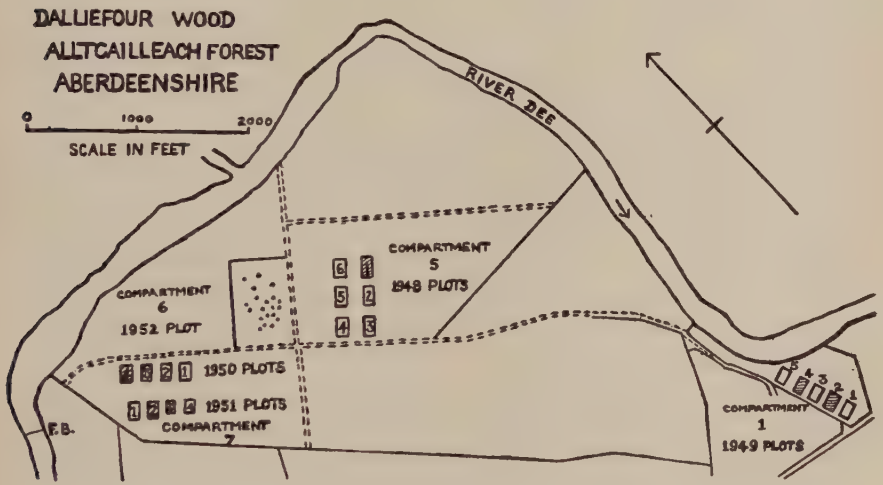

FIG. 1

Geology and soil. River terrace adjoining right bank of River Dee. River gravels and sands overlying glacial drift. Underlying rock felspathic gneiss. Soil podsolic, with a clearly defined A_2 horizon showing leaching. No pan formation. Drainage free.

Ground vegetation. Mosses (*Hylocomium splendens* abundant), *Vaccinium myrtillus* and *V. vitis ideae* frequent, *Calluna vulgaris* occasional.

Tree crop. Practically pure Scots pine (*Pinus sylvestris* L.) with very occasional European larch (*Larix decidua* Mill.)

HISTORY AND DESCRIPTION OF THE STAND

The woods were acquired by the Forestry Commission in 1933. Records of the original planting are not reliable and there is no knowledge of the origin of the planting stock. From the present appearance of the trees there is every reason to believe that the seed used was collected locally, and the existing stand is very typical of the Scots pine plantations of the Dee valley. Ring counts show the age

of the crop to be between 63 and 72 years at the time of the observations. Details of the crop in the plots used for cone and seed counts are given in Table I and the location and distribution of the plots is shown in Fig. 1. The average number of stems per acre at the time of making the cone counts was 380 and the quality class of the crop, according to the Forestry Commission yield tables for 1928, is between II and III (slightly over quality Class III according to the new yield tables). The crops had been thinned six or seven years prior to the operations yielding the material for the cone counts. On these occasions an average of 115 stems per acre were removed, yielding 520 Hoppus cubic feet per acre.

It will be observed from Fig. 1 that different compartments of the forest were used in different years to provide material for these investigations; this is explained more fully in the following description of the method used. The compartments concerned are all contiguous and represent a purely administrative subdivision of a block of forest which shows little variation in age, has been treated silviculturally in the same manner, and which occupies a remarkably uniform site. In no case were the plots of one year far distant from those of the preceding year and the stand used can be considered homogeneous for all practical purposes.

It is of interest to note that, immediately adjacent to the plots used for these observations, natural regeneration of Scots pine has been very successfully obtained following uniform system methods, and in areas, also adjacent, where clear fellings were made in 1940 and 1941, considerable stocking with natural seedlings has taken place. Throughout the plots used for cone counts frequent natural regeneration of Scots pine was observed and there is little doubt that the stand used for these observations could be regenerated naturally.

METHOD

The observations and investigations were made in connection with an annual practical course in forest mensuration for students of Aberdeen University held during the Easter vacation each year at Alltcailleach forest.

The first cone collections were made on 31st March 1948 and continued each year at the same time of the year until 1952. At the time of collection all mature cones were closed and seedfall had not commenced. The trees from which the cone collections were made were those felled in the course of thinning exercises except in the case of the 1953 collections when, as later explained, trees resulting from windthrow were used.

In all cases the thinning plots were first thinned on a 'B' grade thinning and then further thinned to a 'C' grade. For purposes of seed collection only the additional trees felled to reach the 'C' grade intensity were used, the 'B' grade thinnings being ignored.

All trees marked for thinning were classified before felling according to the modification of Schädelin's system used by the Forestry Commission. Thus information was available regarding the canopy class, stem form and crown development of all trees eventually selected for cone counts.

In order to ascertain maximum cone and seed production it would have been

preferable to use the largest dominants in the crop but, apart from this being impracticable in the circumstances, the method used provided valuable information regarding cone production in relation to dominance because among the thinnings dominants, co-dominants, and sub-dominants occurred. Furthermore, the method provided a suitable means of making periodic comparisons.

The thinning plots were rectangular, 3 chains long by 1½ chains wide, giving an area of 0·45 acre (for topographical reasons plots numbers 3 and 4 in 1951 were 0·3 acre). These plots were laid out systematically in rows, with an intervening space or corridor of 1 chain between plots. In the 1948 collections one plot out of the six laid out was selected for cone counts, but in the subsequent years two plots out of the total laid out were selected. In every case the plots chosen were selected by drawing lots.

Within each randomly selected plot a sample of ten trees was chosen by placing the enumeration numbers of the trees felled to make up the 'C' grade thinning in a hat and the first ten numbers picked out were used for cone counts. The trees thus selected were then located and all mature cones were hand picked from the crowns and counted.

In the case of the 1948 and 1952 collections, which were much heavier than those of the intervening years, 10 per cent. samples of the total numbers of cones per tree were taken and placed in bags which were then sealed. In the case of the other years the total crop of mature cones was similarly bagged for each tree.

In the year 1952 no thinning exercise was carried out. Following the severe gale of 24th December 1951 a considerable number of trees in the woods used for the earlier counts were thrown. From among these, 20 leaning but not prostrate trees were selected and felled and the cone crop counted as already described. The stand from which these trees were selected was indistinguishable from those used for previous counts, and comparison with the tree-classification data shows that the number of dominants and co-dominants is very similar.

The sealed bags containing the cones were kept indoors at room temperature and subsequently opened and the number of shed seeds counted four months after collection. All cones were lightly tapped to release all free seeds which were then counted and placed in envelopes bearing the individual tree number. Seeds were divided into mature and immature and the numbers of each category recorded for each tree.

At the time of making the seed counts notes were made regarding the type of cone and also the degree to which opening had taken place. At the same time observations were made on the variation of seed form, colour, &c. and notes kept of the yields of seed from different cone types.

From 1949 onwards an attempt was made to see if the number of cones per tree could be reasonably accurately estimated by eye. Each tree selected for detailed count was first visually examined and an estimate of the cone crop noted. These estimates were subsequently compared with the detailed complete count. All individual counts and estimates were done by the author and in no case were any other observers employed.

The results of all observations made are consolidated in Table II.

RESULTS

An examination of the data recorded in Table II discloses certain important facts; these are briefly summarized as follows:

1. The number of cones per tree and the number of seeds, both mature and immature, per tree was much greater in 1948 and 1952 than in any other year during the period covered by observation.
2. In every sample of trees examined there was considerable variation in the number of cones produced by individual trees, and in every sample there was at least one tree without any cones.
3. The number of seeds per cone varies very considerably. It was observed during the seed counts that cones varied markedly in the time taken for them to open: some cones remained tightly closed even after several years.
4. The proportion of mature to immature seeds varies with individual trees.
5. The cones collected exhibit very obvious variation, differing in size, shape, taper, smoothness, and colour. All these features were constant for individual trees. An equally wide range of variation was observed in the seed. Without a systematic classification of cone and seed characteristics for the species it is not possible to draw any definite conclusions regarding correlations between cone types and seed production.
6. The trees selected for cone counts included dominants, co-dominants, and sub-dominants and showed variation of crown and stem form within their canopy classes.

STATISTICAL ANALYSIS

The figures entered in Table II were examined statistically and the following conclusions arrived at:

1. The number of cones produced in 1948 and 1952 was significantly greater than in the other years ($P<0{\cdot}001$). There was no significant difference between the numbers produced in 1948 and the numbers produced in 1952, nor between the numbers produced in the other three years.
2. Exactly the same conclusions may be drawn about the number of mature seeds and the number of immature seeds.
3. Dominance in the seed bearers is significantly associated with (*a*) cone production ($P<0{\cdot}001$) and (*b*) mature seed production ($P<0{\cdot}001$).
4. There is no evidence of any association between crown form and either cone production or mature seed production.
5. In the absence of a systematic classification of cone types it was not possible to apply statistical methods. Notes and observations suggest that comparatively smooth cones with a length-breadth ratio of 1·9 to 2·1 produce the largest numbers of seeds.
6. The visual estimate of cone numbers bore a fairly close relationship to actual cone number and it was estimated that, if the visual estimate were translated into numerical terms, 19 trees out of 20 would be within a factor 4 of their true value.

METEOROLOGICAL DATA

In order to see if any connexion could be established between the numbers of cones and seeds produced annually and meteorological data, the monthly supplements to the Daily Weather Reports of the Meteorological Office were carefully examined.

The nearest Meteorological station to the area of cone collection is Dyce, Aberdeenshire, which is approximately 34 miles in a direct line from Ballater. In the absence of any more local data the information recorded at Dyce was used. It is not considered that any significant differences between the climate at the station and at the forest are likely.

The weather information examined included maximum and minimum temperatures, numbers of days with ground frost, numbers of hours of sunshine, rainfall, and numbers of days with snow or sleet.

It is not easy to find in this wealth of information the secret of the seed years occurring in 1948 and 1952. There is no doubt that the explanation of these significant cone and seed crops is by no means a simple one. Even if climatic phenomena are observed which suggest physiological responses, it is reasonable to believe that, after a heavy output of seed, the mother trees require a period during which reserves must be built up before another seed crop is produced.

The search for climatic clues was centred on an examination of the meteorological conditions most likely to influence the early life and development of the young fertilized female flowers, including the fertilization itself, and also those conditions which may affect the growth and development of the cones in the year directly prior to the year of seed fall. The factor considered of greatest importance in the north-east of Scotland in influencing the flowering of the Scots pine is the maximum daily temperature especially during the months of March, April, May, and June. A factor affecting the production and flow of pollen and the process of fertilization may be the amount of sunshine. Consequently, special attention was paid to the maximum temperatures recorded, especially for the years 1946 and 1950 as the years when the flowers, resulting in the cone crops of 1948 and 1952, were formed. Sunshine figures for the years 1947 and 1951 were examined to see if these indicated a relationship between fertilization and seed production.

An examination of the maximum daily temperatures covering the months of March to June inclusive for the years 1945 to 1951 shows that in 1946, and again in 1950, spring temperatures were markedly above the average calculated over a long period, while in 1947 and 1951 these temperatures were well below the average. Over the period under review the highest monthly average for the month of April was in 1946 and for the months of May and June was in 1950. A further feature of the temperature figures is that for the months of March to June the general pattern for the years 1945, 1946, and 1947 is very similar to that for the years 1949, 1950, and 1951. As these are the years immediately preceding the two well marked seed years the similarity of temperature fluctuation may be important.

The hours of sunshine for the growing period June to September were above average for the years 1947 and 1951, but the additional sunshine in 1947 was very marked and much higher than for any other year during the period. This may be

of importance in explaining the higher percentage of mature seeds in the 1948 crop (91·1 per cent.) as compared with the 1952 crop (82·5 per cent.).

The monthly rainfall figures do not appear to indicate any marked linkage with cone production. It would appear that the patterns of rainfall distribution during 1946 and 1950 are more similar than between any other two years. The summer rainfall following an abnormally dry spring in both cases may be of significance as occurring in the years when the cone crops of 1948 and 1952 originated.

CONCLUSIONS

It is now possible to answer, as far as these particular observations are concerned, the original questions set. The following are the principal conclusions:

1. In a typical stand of quality class II/III Scots pine in north-east Scotland marked and significant annual fluctuations of cone and seed output occur. In the stand observed maximum production of both cones and seed occurred in the years 1948 and 1952.
2. In the case of plantation grown Scots pine, 60 to 70 years old, the average number of mature cones per tree is between 229 and 315 in years of maximum production, i.e. in seed years. In intervening years the number of cones per tree may vary from 11 to 23.
3. The number of seeds per cone varies within wide limits as does the proportion of mature and immature seed. The average number of mature seeds per cone in 1948 and 1952 was 12 and 7 respectively.
4. There is significant association between dominance of the seed bearers and both cone and seed production. In the tree classification a canopy class of 1 corresponds to high cone and mature seed production and canopy class 3 to low production.
5. Great variation is to be found in the cone types in a 60–70 year old Scots pine stand established in Scotland by direct planting methods. From the observations made there was not sufficient evidence to establish any significant association between cone type and seed production.
6. No clear and simple relationships could be discovered between meteorological records and the occurrence of seed years, but there is evidence to suggest that the more the maximum daily temperatures occurring during the time of flowering, and the number of hours of sunshine during the year of fertilization, exceed the average, these factors may have a favourable effect on seed production.
7. It is possible to estimate visually with a high degree of accuracy the number of cones occurring on a single tree.

ACKNOWLEDGEMENTS

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TABLE I. *Details of crop Dalliefour Wood, Alltcailleach Forest*

				Main crop									*Thinnings*					*Total crop*	
Compt. no.	*Plot no.*	*Species*	*Date*	*Age (yrs.)*	*No. of trees after thinning per acre*	*Top height (ft.)*	*Mean height (ft.)*	*Form factor*	*Mean Q.G. at B.H. (in.)*	*Basal area per acre (sq. ft.)*	*Volume u.b. per acre (Q.G.Cub. ft.)*	*Bark %*	*No. of trees per acre*	*Mean height (ft.)*	*Mean Q.G. at B.H. (in.)*	*Basal area per acre (sq. ft.)*	*Volume u.b. per acre (Q.G.Cub. ft.)*	*Basal area per acre (sq. ft.)*	*Volume u.b. per acre (Q.G.Cub. ft.)*
5	1	S.P.	31/3/48	68	333	52	45·5	0·345	63	109	1,583	10·5	78	44·2	6^2	23	330	132	1,913
1	2	S.P.	29/30th/3/49	72	323	74	56·5	0·410	7^2	126	2,731	10·0	97	54·2	6^2	28	674	154	3,405
,,	4	S.P.	,, ,,	72	330	62	54·0	0·388	7	121	2,581	11·0	113	50·0	5^2	26	518	147	3,099
7	3	S.P.	29/30th/3/50	63	227	57	54·6	0·345	8	107	1,922	10·6	116	47·4	6^2	37	590	144	2,512
,,	4	S.P.	,, ,,	63	222	63	55·0	0·298	8	105	1,825	11·6	75	51·3	6	19	356	114	2,181
7	2	S.P.	4.4.51	64	269	60	56·0	0·406	8^1	164	2,786	9·4	102	48·9	6^2	39	589	203	3,375
,,	3	S.P.	,,	64	213	60	55·5	0·412	8^2	237	2,028	15·6	160	47·4	6^2	47	880	284	2,908
6	x	S.P.	20/21st/3/52	68	x	x	x	x	x	x	x	x	x	53·3	7^2	x	x	x	x

x Details not available, counts made from wind-thrown trees.

TABLE II. *Details of cone and seed counts 1948 to 1952*

Date of cone collection	*Plot no.*	*Tree no.*	*Visual estimate of no. of cones per tree*	*Total no. of cones*	*Number of seeds per tree*		*Number of seeds per cone*		*Tree classification*
					Mature	*Immature*	*Mature*	*Immature*	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
31 Mar. 1948	1	110	..	0	..	..	..	..	312
	,,	48	..	337	3,043	218	9·0	0·6	212
	,,	66	..	569	11,750	797	20·7	1·4	211
	,,	34	..	67	479	383	7·1	5·7	233
	,,	7	..	28	121	243	4·3	8·7	231
	,,	11	..	564	1,873	252	3·3	0·4	223
	,,	89	..	120	2,100	300	17·5	2·5	324
	,,	57	..	137	2,789	186	20·4	1·4	323
	,,	76	..	81	942	10	11·6	0·1	222
	,,	180	..	386	4375	168	11·3	0·4	233
		10	..	2,289	27,472	2,557	..	..	..
29/30 Mar. 1949	2	9	Very few	1	0	0	0	0	212
	,,	48	Very few	7	72	8	10·3	1·1	233
	,,	52	Few	44	579	57	13·2	1·3	123
	,,	21	None	0	..	..	..	..	322
	,,	59	None	0	..	..	..	..	322
	,,	76	None	1	26	4	26·0	4·0	133
	,,	69	None	1	0	0	0	0	322
	,,	105	Very few	3	18	2	6·0	0·7	133
	,,	119	Few	69	590	60	8·6	0·9	133
	,,	126	Very few	5	111	11	22·2	2·2	223
	4	4	Very few	10	159	15	15·9	1·5	233
	,,	19	None	0	..	..	..	..	323

	„	65	Very few	6	137	4	22·8	0·7	232
	„	75	None	0	..	..	..	..	322
	„	96	Very few	15	161	30	10·7	2.0	222
	„	33	Few	19	131	12	6·9	0·6	233
	„	61	None	0	..	..	..	..	322
	„	11	None	0	..	..	..	..	322
	„	79	Very few	63	774	89	12·3	1·4	322
	„	131	Very few	3	79	0	26·3	0	222
		20	..	247	2837	292	..	..	..
29/30 Mar. 1950	3	96	Many	189	303	105	1·6	0·6	233
	„	115	Few	92	488	172	5·3	1·9	123
	„	9	Very few	24	23	53	1·0	2·2	233
	„	102	Very few	14	38	31	2·7	2·2	233
	„	56	Very few	9	6	5	0·7	0·6	332
	„	5	Few	8	0	0	0	0	222
	„	65	Very few	3	13	3	4·3	1·0	422
	„	33	None	0	..	..	..	..	322
	„	40	None	0	..	..	..	..	322
	„	82	None	0	..	..	..	..	222
	4	61	Very few	12	65	4	5·4	0·3	332
	„	46	Very few	9	0	0	0	0	222
	„	114	None	1	12	1	12·0	1·0	312
	„	44	None	1	6	3	6·0	3·0	222
	„	91	Few	45	31	1	0·7	0	232
	„	79	Few	25	49	54	2·0	2·2	232
	„	30	Very few	32	12	25	2·7	2·1	221
	„	32	None	0	..	..	..	..	423
	„	26	None	0	..	..	..	..	232
	„	53	None	0	..	..	..	..	222
		20		444	1,066	457	..	..	..

TABLE II. *Details of cone and seed counts 1948 to 1952 (cont.)*

Date of cone collection	*Plot no.*	*Tree no.*	*Visual estimate of no. of cones per tree*	*Total no. of cones*	*Number of seeds per tree*		*Number of seeds per cone*		*Tree classification*
					Mature	*Immature*	*Mature*	*Immature*	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
4 April 1951	2	9	Few	13	143	18	11·0	1·4	223
	,,	69	None	0	..	..	..	..	222
	,,	88	Very few	12	190	38	15·8	3·2	223
	,,	96	Very few	14	142	31	10·1	2·2	232
	,,	98	None	0	..	..	..	..	222
	,,	113	None	2	0	0	0	0	223
	,,	114	None	0	..	..	..	..	222
	,,	136	None	3	69	3	23·0	1·0	222
	,,	162	Very few	6	107	1	17·8	0·2	222
	,,	166	None	0	..	..	..	..	233
	3	21	Few	32	96	315	3·0	9·8	222
	,,	29	Very few	30	388	34	12·9	1·1	232
	,,	37	None	0	..	..	..	..	133
	,,	52	Very few	4	38	25	9·5	6·2	333
	,,	63	Very few	9	103	5	11·4	0·6	222
	,,	73	None	7	136	18	19·4	2·6	322
	,,	87	Very few	9	15	21	1·7	2·3	222
	,,	90	Few	43	0	0	0	0	223
	,,	97	None	0	..	..	..	..	223
	,,	106	Few	41	228	45	5·6	1·1	232
		20		225	1,655	554			

20/21 March 1952	..	1	Many	253	2,890	101	11·4	0·4	113
	..	2	Many	254	8,515	589	33·5	2·3	222
	..	3	Very many	676	7,516	4,136	11·1	6·1	123
	..	4	Fairly many	147	627	245	4·3	1·7	213
	..	5	Few	45	387	9	8·6	0·2	212
	..	6	Few	149	1,331	1,381	8·9	9·3	221
	..	7	Few	59	1,800	10	30·5	0·2	122
	..	8	Fairly many	210	0	0	0	0	222
	..	9	Fairly many	464	464	161	1·0	0·3	213
	..	10	Fairly many	379	7,271	180	19·2	0·5	223
	..	11	Fairly many	467	328	437	0·7	0·9	213
	..	12	Few	128	2,796	49	21·8	0·4	213
	..	13	Fairly many	242	413	313	1·7	1·3	231
	..	14	Few	43	161	0	3·7	0	232
	..	15	Fairly many	200	1,090	40	5·4	0·2	232
	..	16	Many	820	530	720	0·6	0·9	133
	..	17	Fairly many	331	0	0	0	0	Diseased
	..	18	Fairly many	294	233	375	0·8	1·3	211
	..	19	Many	630	3,920	260	6·2	0·4	212
		20	Fairly many	501	2,395	60	4·8	0·1	223
		20		6,292	42,667	9,066	..	..	..

NOTE

In the tree classification used in column 10 of Table II, the figures read from left to right refer to Dominance, Stem form, and Crown and the interpretation is as below.

1 - - Dominant, 2 - - Co-dominant, 3 - - sub-dominant, 4 - - suppressed.
- 1 - Good stem form, - 2 - Slightly defective stem form, - 3 - Badly defective stem form.
- - 1 Good crown, - - 2 Slightly defective crown, - - 3 Very defective crown, - - 4 Whip.

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THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, LIVERPOOL, 1953

EXCURSIONS undertaken by the Forestry sub-section included visits to two Forestry Commission forests, to the Duke of Westminster's estates at Eaton, to J. R. Gordon and Co.'s saw-mill at Queen's Ferry and Messrs. Evan's saw-mill at Widnes, and to Freshfield to see the afforestation of sand dunes. At joint sessions with the Botany section, the Forestry Commission film *The Culbin Story* was shown and Dr. Blanchard illustrated an excellent paper on the ecology of 'the wet slacks' with some really lovely colour photographs. The high standard set by past meetings was well maintained both in the papers read, the excursions undertaken and in the general excellence of the arrangements made.

The following papers on forest subjects were read at the meeting. Mr. R. W. Gloyne's paper is included in this number of *Forestry* and several of the others have been published elsewhere.

Mr. A. P. Long (Chairman Forestry Sub-section): *The place of Forestry in Britain's economy.*

Mr. Lloyd O. Owen: *The Development of Operational Woodland Societies in the United Kingdom.*

Mr. W. D. D. Evans: *Forestry for the Private Owner.*

Mr. W. T. Smith: *Private Woodlands: The Preparation, Conversion and Marketing of Produce.*

Mr. R. W. Gloyne: *Some Effects of Shelter-belts upon Local and Micro Climate.*

Mr. W. A. Cadman: *Forestry Aspects of Shelter-belts for Hill Farms.*

Professor J. E. Nichols: *Shelter-belts in Relation to Hill Farming.*

At the joint sessions with the Botany Section, the following papers read were particularly concerned with forestry.

Mr. P. Thaarup: *The Afforestation of Sand Dunes on the Western Coasts of Jutland, Denmark.*

Mr. James Macdonald: *The Afforestation of Sand Dunes in Britain.*

Dr. C. R. Metcalfe: *The Effects of Smoke Pollution on Vegetation, with special reference to Kew Gardens.*

Dr. J. K. A. Bleasdale: *Results of some controlled experiments with Sulphur Dioxide on Vegetation.*

Mr. T. R. Peace: *Some Effects of Pollution from a Brickworks in Bedfordshire.*

The meeting this year is in Oxford (1 to 8 September). Mr. W. E. Hiley is Chairman of the Forestry sub-section and is to speak on the influence of forest economics on forest policy. Joint sessions are intended with Zoology (animal pests) and with Botany (soil problems). There are excursions to the Chilterns, to Alice Holt, to Princes Risborough, and to Cirencester. In 1955, the meeting is in Bristol (31 August to 7 September), in 1956 in Sheffield and in 1957 in Dublin.

THE AFFORESTATION OF CHALK DOWNLAND

By L. C. TROUP

SUMMARY

The downland scene is described with particular reference to the South Downs of Sussex and Hampshire. An outline is given of the topographical, climatic, and soil factors which influence the choice of species and methods of afforestation. The soil changes which take place under the influence of humus are discussed and related to types of vegetative cover. Beech (*Fagus sylvatica* L.) is the main tree species favoured and methods of raising this tree are considered for the various sites available. The preparation of the ground for planting may necessitate complete or partial cultivation or the thinning of existing cover. Methods of doing this are described.

INTRODUCTION

THE afforestation of bare downland and the reforestation of the frequently uneconomical crops which cover the gentler slopes and fill the valley bottoms, are problems which have received much attention during the past 20 or 30 years. It has indeed become clear that we are dealing with a very specialized branch of silviculture, and one that is not yet fully understood in all its details. This paper attempts to define the conditions one may expect to encounter and points to methods of approach—some of which are well tried, and some of which are experimental. It is as well to note, however, that the paper is based upon a particular study of the South Downs in Sussex and Hampshire. How far it is applicable to other areas readers must judge for themselves.

TOPOGRAPHY

The typical downland scene is one of well rounded hills, rather flattened at the top and characterized by fairly gentle slopes. Steeper slopes are, however, not infrequent and escarpments may be quite precipitous. The highest hills rise some 800 feet above sea level, but often appear higher by virtue of their sudden ascent from the relatively level Weald. Some of the valleys carry seasonal streams, but for the most part they are dry. These valleys, which describe various patterns through the chalk, give rise to a multitude of local variations producing the diverse microclimates whose importance is stressed below.

CLIMATIC FACTORS

The average rainfall is in the region of 28 inches, but the actual precipitation varies from place to place, and in some areas it may be significantly lower than this. Again, its value in terms of tree growth will depend upon the soil and the vegetative cover upon which it falls, and upon the individual aspects and exposures concerned. Downland soils are typically thin and available moisture may often be a critical factor in the establishment of a crop. South-facing slopes are especially subject to the drying agencies of wind and sun, more particularly if they are

devoid of scrub or tree cover. But loss of moisture is a factor to be reckoned with wherever thin soils occur, irrespective of aspect and exposure; south-facing slopes are merely likely to present a general problem in its extreme form. Slopes facing the prevailing winds suffer from the further disadvantage that leaf litter is frequently dispersed, and the advantages of its breakdown are lost to the area of its origin.

Beech planted in the open often suffer from insolation. It appears that the moisture content of the soil is not sufficient to enable the trees to transpire quickly enough to keep the leaf temperature below the killing-point. Thin, southerly slopes are most subject to this very common sort of damage.

Frost is significant in so far as it may affect the choice of species and type of silviculture in the valley bottoms. In general it is not a factor of much importance.

GEOLOGY AND SOIL

The area under particular review in this paper lies on the dip slopes of the upper chalk, although the middle chalk outcrops narrowly along some of the slopes. It appears certain that most of the soils have been derived directly from the parent chalk. Even the deeper valley soils can be accounted for by local deposition of material produced at the higher levels. There are, however, exceptions, and transported material may produce soil types differing from those described below.

In its breakdown the chalk has produced and continues to produce a variety of soil types. Basically the development is one from shallow soils to deep soils; from rendzinas to brown earths; from thin, highly calcareous soils to deep, leached forest soils. But this process can be modified by local topography, and its progress depends upon the vegetative cover, for as Duchaufour (2) has shown organic matter plays the central part in such transitions.

The typical soil found under open downland conditions and on the steeper slopes is a rendzina. This is characterized by a dark, shallow profile possessing an abundance of free calcium carbonate. Beneath this crumby material lies chalk which shows a variable degree of fissuring: the middle chalk is generally not so fissured as the upper. Into these fissures the dark soil is seen to percolate, and the roots follow the soil downwards. Flints are generally present in the upper chalk. Under the influence of humus produced by the grass and by invading shrubs and tree species, the amount of free calcium carbonate decreases and the humus accumulates in a fully flocculated, neutral state. Eventually the remaining, free calcium carbonate in the profile largely disappears and the humus itself begins to suffer desaturation. Soils of this type are often called rendziniform forest soils. They are still relatively shallow and are characterized by a good crumb structure. These soils develop still further under the influence of woodland conditions. Now the humus becomes reduced in quantity, its rapid decomposition being assured by the improving conditions for soil microfauna. Leaching begins to take place, the humus acting as a protective colloid to the clay particles which accumulate at a lower level. The soil has now developed into a leached brown earth, and this is the climax condition.

The process described above is naturally gradual and all transitions between

rendzina soils and rendziniform forest soils and between rendziniform forest soils and leached brown earths can be found. Indeed in many downland areas one can follow the entire process by merely passing from one valley side to the next. This evolution does not, however, take place in all conditions. Steep slopes afford a clear exception, for here there is constant replacement for the lost free calcium carbonate. Here, broadly speaking, the soil remains a rendzina, although scrub and planted crops may partially arrest this rejuvenation and allow restricted development towards a transitional soil. The other exception is one of particular interest since it involves the development of 'downland heath' conditions, which are discussed below. These may be found on the relatively flat ground at the higher levels. Here the upper soil has become distinctly acid since the removal of free calcium carbonate has not been compensated by fresh supplies from higher levels.

It has been pointed out by Duchaufour that it is possible to have the very reverse of the soil evolution which has been described. This 'regressive evolution' may follow the clear felling of tree crops; the soil slowly decreases in depth and becomes recharged with calcium carbonate, taking on the character of a rendzina. Grazing animals could produce a similar regression, but over a longer period.

VEGETATION

In the process of soil development described, soil and vegetation interact: the soil is improved by the humus derived from the vegetation, and this improvement makes possible a richer and more exacting vegetation; this in turn produces a heavier humus and the soil changes are thereby hastened. It thus becomes possible to associate broadly particular groups of vegetation with the different soil types.

The open downlands usually show soil types approximating to the rendzina. Where grazing takes place the dominant grasses are sheeps fescue (*Festuca ovina* L.) and red fescue (*Festuca rubra* L.). In the driest situations sheeps fescue is commoner than the red. Where grazing is light or absent other grasses often assume dominance; the most frequent are common oat-grass (*Avena pratensis* L.), Yellow oat (*Trisetum flavescens* Beauv.), and upright brome (*Bromus erectus* Huds.); whilst false oat-grass (*Arrhenatherum elatius* M. and K.)—a plant markedly intolerant of grazing—is often found. Tor grass (*Brachypodium pinnatum* Beauv.) sometimes assumes local dominance. Together with the grasses, many herbs are found. Perhaps the most frequent of these are wild thyme (*Thymus serpyllum* L.), salad burnet (*Poterium sanguisorba* L.), birds-foot trefoil (*Lotus corniculatus* L.), and purging flax (*Linum catharticum* L.). When grazing animals—sheep and rabbits—are excluded the close-knit, downland turf very quickly gives way to the grass association noted above. Where rabbits are numerous the turf remains close cropped, and where they are in very large numbers vegetation may almost disappear from some of the affected areas.

The diminution of grazing is associated with the invasion of various downland shrubs. These are principally, juniper (*Juniperus communis* L.), hawthorn (*Crataegus* spp.), elder (*Sambucus nigra* L.), dogwood (*Cornus sanguinea* L.), privet (*Ligustrum vulgare* L.), wayfaring tree (*Viburnum lantana* L.), blackthorn (*Prunus*

spinosa L.), and various roses. The roses are often the first colonists but they are quickly followed by the other species. Juniper is an early colonist of thin soils and hawthorn an early colonist of the deeper soils. The first tree species to assert themselves are whitebeam (*Sorbus aria* Crantz.), yew (*Taxus baccata* L.), ash (*Fraxinus excelsior* L.), and beech (*Fagus sylvatica* L.); gean (*Prunus avium* L.) and holly (*Ilex aquifolium* L.) are occasionally found. As the scrub develops, so the light-demanding downland flora diminish and woodland or marginal woodland species appear: thus dogs mercury (*Mercurialis perennis* L.) and false brome grass (*Brachypodium sylvaticum* R. and S.) become quite characteristic.

Where 'downland heath' conditions occur the ground vegetation consists of such calcifuge plants as ling (*Calluna vulgaris* Hall), bell heather (*Erica cinerea* L.), and tormentil (*Potentilla erecta* Hampe). Chalk is, however, still close to the surface and calcicolous shrubs are often found mixed with hawthorn, blackthorn, and gorse (*Ulex europaeus* L.). Bracken (*Pteris aquilina* L.) is common. Under these conditions oak (*Quercus* spp.) is often a leading tree colonist, sharing dominance with ash although beech is usually present.

The evolution from grassland to scrub is accompanied by the soil changes already described. The continued invasion of tree species gradually changes the character of the scrub until it develops into woodland consisting of variable admixtures of oak, ash, beech, and minor species. The ground flora changes into a true woodland type and, in addition to dogs mercury, wood sanicle (*Sanicula europaea* L.), bluebell (*Scilla nonscripta* L. & H.), &c., appear; bramble (*Rubus fruticosus* L.) also becomes common. Ultimately the beech assume dominance and this is the climax condition—a condition associated with the formation of leached brown earths, with the exception of steep slopes, where rendzina conditions may persist.

Pure, or nearly pure, yew woods form an interesting exception to the evolution described. Where beech seed is lacking yew may establish local dominance; the heavy shade cast by this tree coupled with its longevity effectively keep invading species at bay.

PAST HISTORY

It appears likely that the downs were largely forest covered during the Atlantic Period (5500–2500 B.C.). It was towards the end of this period that Neolithic man began to graze sheep and he would, no doubt, choose first the more open slopes and summits. As his activities extended some deforestation would be inevitable, but perhaps more would be caused indirectly by grazing animals than by Neolithic man himself. The Sub-Boreal Period which followed the Atlantic and lasted until about 500 B.C. was warmer and drier. Tree growth on unretentive upland soils would be bound to suffer, and it seems likely that in the Bronze Age the downs had already become virtually treeless. There were also fairly considerable cultivations over the chalk and these continued throughout the Roman occupation. In many places 'Celtic fields' are found in a good state of preservation. These fields are bounded by low, stony banks called 'lynchets' and form a characteristic feature of the downland scene.

The later history is one of intensive sheep grazing continuing down the years, until the industry fell into decline during the present century. Now, very few flocks graze the open downland and the sight of wandering sheep, familiar for 4,000 years, has become a rarity. Previously well-grazed downland has now become rough grassland or scrub where rabbits have not been present in excessive numbers. Thus one can envisage a gradual return to forest conditions over large areas. Our present need cannot, however, await the slow reward of nature, and extensive tracts of downland are now being planted, as part of the overall afforestation programme of 3 million acres.

SILVICULTURAL CONSIDERATIONS

The silvicultural problems of afforestation are as varied as the soils and the vegetative cover and are considered below under (I) *choice of species*, (II) *nurses and mixtures*, and (III) *preparation of the ground and planting*. No overall prescription is possible, and often one soil or vegetative type merges gradually and almost imperceptibly into the next. It is, however, convenient to distinguish four types: open downland, scrub, uneconomical woodland, and yew forest.

(I) *Choice of species*. On rendzina or rendziniform soils, which in practice can be related to open downland or to scrub conditions, beech is the inevitable final crop tree. Where brown forest soils have developed, there is often a mixed crop of birch and ash which, though of low economic value, is of great silvicultural significance. Here a wider selection is possible and, as it is pointless to sacrifice woodland conditions by clear felling to favour a light demander, shade bearers are usually chosen, the chief of which is again beech but Douglas fir (*Pseudotsuga taxifolia* Brit.) has also been planted and other useful species are Western red cedar (*Thuja plicata* D. Don) and Lawson cypress (*Chamaecyparis lawsoniana* Parl.). Recently clear felled woodlands may allow the establishment of a light demander, if desired, and the fertility of the soil will often point to oak. Ash and sycamore (*Acer pseudoplatanus* L.) often regenerate profusely and where these occur they will be accepted as part of the crop, if their vigour and promise should warrant it. A word of warning is necessary here: ash on thin soils grows with great vigour for perhaps 10 years, but thereafter slows down considerably and usually comes to nothing. Sycamore is much more valuable but shares with beech the dubious distinction of being the favourite prey of the grey squirrel. This consideration may lose its force as the campaign against the squirrel progresses.

(II) *Nurses and mixtures*. Many downland areas offer exceedingly inhospitable conditions for the establishment of beech. Furthermore in nature beech is never the pioneer crop, so in an attempt to copy nature in some degree, nurse trees are frequently planted concurrently with the beech. To be effective a nurse species must be able to withstand adverse climatic factors, and must exceed the general height growth of beech until it has fulfilled its function. This stage will be reached when the beech are firmly established and are, in themselves, producing a more favourable microclimate. An evergreen nurse is clearly more suitable for this purpose than a leaf tree. Conifers not only give more effective protection by reason of their persistent foliage, but they usually, when properly selected, exceed

the growth of beech in the initial stages. The limiting factor is the length of life which can be attained by a conifer on calcareous soils. The life span will vary with the depth of the soil and with the species employed. Furthermore *Fomes annosus*, *Armellaria mellea*, and lime-induced chlorosis are common enemies. Exacting conifers certainly have no place in rendzina soils, and on the better soils one may find that the natural cover—whether it be scrub or uneconomic woodland—affords adequate nursing material, making the deliberate planting of nurses unnecessary for early nursing, however desirable mixtures may be for other reasons, e.g. the provision of an early return of saleable produce and the improvement of the form of beech under continuing conditions of partial shade as recorded by Brown (I).

Individual nurse species including hardwoods and shrubs are considered below.

Scots pine (*Pinus sylvestris* L.). One of the best nurses for difficult sites, but on rendzina soils it cannot be expected to live for more than about thirty years.

Corsican pine (*P. nigra* var. *calabrica* Schneid). This tree is more at home on calcareous soils than Scots pine, and may survive 10 or 20 years longer under similar conditions. It suffers the disadvantage of being more difficult to establish, and is likely to show slower initial growth.

Austrian pine (*P. nigra* var. *austriaca* Asch.). Probably more at home on chalky soils than most conifers. In exposed conditions it may do better than any other nurse. Its form is deplorable, however, and it should be avoided excepting in the most difficult situations.

European larch (*Larix decidua* Mill.). Valueless on thin soils and in exposed places. On the better soils it is likely to make an effective nurse.

The Monterey Cypress (*Cupressus macrocarpa* Hartweg). A distinctly promising nurse which is unfortunately hard to establish. It withstands exposure well.

Western Red Cedar (*Thuya plicata* D. Don). This tree has done very well experimentally, and has shown vigorous growth on rendzina soils. Its large-scale use cannot yet be recommended, however.

Norway spruce (*Picea abies* Karst.). On the better soil types, and especially in frosty localities, this tree sometimes finds a place.

Birch (*Betula* spp.). This has not often been used as a nurse, and if planted at the same time as the beech is likely to give little initial protection.

Grey alder (*Alnus* spp.). Quite valueless on thin soils but effective on deeper. It is a soil improver.

Lime (*Tilia* spp.). This tree has grown fairly well experimentally, and might find a use on the better soil types.

Whitebeam. A natural constituent of downland scrub, but one that grows too slowly on thin soils to be useful. On the deeper soils it may do well.

Gorse. Not easy to establish and is relatively soon suppressed by the beech. There is therefore only a short period of nursing. It is also difficult to weed. Nevertheless, it is one of the most effective early nurses, and where it occurs naturally, it should be used. It is a soil improver.

Broom (*Cytisus scaparius* Link.). This is easier than gorse to establish as a planted crop, has all its advantages and is easier to weed. The seed is sown direct, a phosphatic manure being applied at the same time.

Ideally the nurse should be planted in advance of the beech either as a complete or as a partial crop. On the better soils, for instance, a complete conifer nurse crop could be planted and left until it reached pit-wood size. Then the whole crop could be thinned at a profit and the beech introduced in groups or in strips. On the poorer soils, a complete nurse crop would be wasteful and the planting of conifers could be partial, leaving space for the later introduction of the beech. Advance planting is, however, the exception rather than the rule and concurrent planting must be considered despite its limitations.

Clearly very intimate mixtures, say alternate rows of pine and beech, are likely to give better initial nursing than any other layout. Disadvantages are that very constant attention is needed lest the nurse suppress its charge and that the nurse in any case will need removing at a comparatively early age. Mixtures of several rows of pine alternate with several rows of beech are therefore favoured. Diverse group planting systems can be evolved, and there is much to be said in their favour, but for ease of management they do not compare with line systems. The exact constitution of a line system must depend on the site and its influence on the probable life of the nurse and the rate of growth of the beech.

An example may serve to make the method clear. It is decided to use Scots pine as a nurse to beech on a thin, rendzina soil. Experience of other localities shows that the Scots pine are unlikely to live for more than 30 years, and that the beech at that stage will be some 20 feet in height. It is thought that the removal or decay of the pine should not leave the outer rows of beech more than 9 feet apart at that point in their development. Clearly, then, only 9 feet can be allowed for the conifer nurse, which will be planted as a single row $4\frac{1}{2}$ feet from the adjacent beech rows. In order to combine efficient nursing with ease of management the final decision may be to alternate two rows of beech with one row of conifer. The rows might be $4\frac{1}{2}$ feet apart overall, and the plants in the rows 3 feet apart. This last spacing may seem to be very close, but on thin soils it is advantageous to form an early canopy; furthermore, the conifers will form more effective nurse lines if the trees are closer than is usual.

Depending then upon the life span of the conifer, and upon the desired distance between the outer beech rows at that age, it is possible to arrive at a logical layout. Within reason the longer the assessed life span of the conifer, the wider apart may be the outer beech rows. On brown earths the consideration may be not so much when the conifer will die as when it will reach marketable size. But here too the aim should be to leave the beech at a calculated density. This sort of information can readily be recorded graphically. Such graphs, suitably amended as experience grows, would form valuable and permanent guides to future action.

With pure crops of beech, capital is locked up for a very long time as early thinnings are at present almost valueless. Mixtures with conifers may therefore be an advantage even where the conifers are not required as nurses. An example would be the dilution of beech with a coniferous shade bearer under a natural cover of say birch and ash. There is furthermore the improvement in the form of beech which is likely to be induced by a nurse species (I).

(III) *Preparation of the ground and planting.* The technique employed will differ

with the terrain and its vegetative cover. It is convenient to consider the problem under the four arbitrary headings, *Open downland*, *Scrub*, *Uneconomical woodland*, and *Yew forest*. Within these headings there will be found all manner of variations, and many areas may possess combinations of all four.

Open downland. The combination of a dense grass mat with a meagre depth of soil makes open downland afforestation a difficult problem. The difficulties are aggravated where conditions of high exposure exist. Furthermore, nothing is quite so unresponsive to the hook as grass, and weeding can be very expensive in plantations which cannot be expected to make rapid initial growth. It is important to note that even a nurse species, deliberately selected for its pioneer qualities, may find such conditions so difficult that its mere survival becomes a matter for congratulation. At best a fairly lengthy period of check can be anticipated unless steps are taken to disrupt the grass mat.

On thin soils, deep cultivation is inadmissable; the humus is dispersed at different levels and bare chalk with flints is liable to be offered as the planting medium. This is as bad as, or even worse than, planting direct into the grass mat. Cultivation may be complete or partial and both systems have their advantages. Partial cultivation consists of treatment confined to the rows along which the plants will be placed. Shallow ploughing at, say, $4\frac{1}{2}$ feet intervals is an example. The trees may be planted on one of the sides of the furrow, or on the upturned turf. In complete cultivation the whole of the planting area is treated. This work can be done by shallow plough, by disk, or by a suitable rotovator. Complete ploughing is obviously more expensive than partial ploughing, but if disks or a rotovator are used, the difference is not very great.

In the writer's experience the best planting mediums have been those produced by heavy disks or by rotovator. The machines used in disking were a so-called 'stump-jump plough' consisting of a series of heavy, spring-loaded disks, and a set of Talbot disks which cross-ploughed the area which had been rather roughly thrown up by the stump jump. A fine planting medium was produced albeit rather gluey in wet weather. The great advantage here is that the top soil remains *in situ*, and it is this top soil which conserves the moisture and holds the readily available nutrients. It is doubtful whether even shallow ploughing can give so good an effect; for patches of bare chalk and flint can hardly escape being brought to the surface to a much greater degree than is the case with disking. Plants will certainly survive and even grow well on ploughed areas, but they would doubtless do even better on disked areas. Furthermore, over conditions that are marginal for tree growth, the retention of the top soil *in situ* may mean the difference between success and failure.

One disadvantage of complete cultivation is that all herbaceous growth is flattened, and the young trees do not have the immediate advantage of the side shade offered by weed species. This can be an important consideration in exposed places, where weeding is often deliberately delayed or confined to the immediate periphery of the plant. It is thought, however, that the advantages of complete cultivation more than counterbalance this. Furthermore, complete cultivation will usually be carried out in the autumn before planting, and not uncommonly

various herbs appear the following summer, especially ragwort (*Senecio*) and sow thistle (*Sanchus*), which together with weakened grass regrowth offer some measure of side protection.

On steep slopes mechanical cultivation may not be possible, and resort must be had to hand screefing of the turf. In some instances the turf has been reversed and placed around the plant in the screefed patch. On thin soils this is a valuable precaution. Screefing should aim to give a good degree of cultivation and although this will double the cost of planting it cannot be neglected. It is quite usual to keep screefing and planting as separate operations. Better work is likely to be obtained in this way.

Great care should be exercised in weeding. Whilst not allowing weed growth to compete with the plant, it is important to keep as much side shade as possible. In addition, limited invasion of the beech rows by downland shrubs should be welcomed rather than discouraged. The light-demanding conifer nurses will usually need earlier weeding than the beech rows, but they, too, will appreciate a degree of side shade on the exposed terrain under consideration.

Scrub. In well-developed scrub areas the grass mat is much more weakly and the flora takes on a woodland or marginal woodland character. Cultivation becomes unnecessary excepting in the larger open areas, which are often present within or alongside the scrub. The scrub should be welcomed and utilized as a nurse to the beech. The problem resolves itself into the best method of introducing the trees. This will vary with the constitution of the scrub, and several common cases will be considered.

(*a*) *Thorn scrub.* Dense areas of hawthorn and blackthorn scrub are often encountered. These have been successfully 'drifted' using a bulldozer with a tooth blade. Protective 'hedges' are left at intervals and the drift planted with pure beech or alternatively in mixture with a conifer.

Where the thorn is scattered or discontinuous, group and strip systems of planting are applicable. There may be scope here for soil cultivation between islands of thorn.

(*b*) *Gorse scrub.* Beech have been successfully raised through gorse, but weeding is difficult and expensive. It is probably better to drift the gorse as described above. A strong gorse regrowth can be expected within the drifts, especially if they are cultivated.

(*c*) *Mixed scrub.* This is the commonest scrub type and consists of thorn, downland shrubs (particularly privet and dogwood), groups of natural ash, some oak, sycamore and birch, and possibly a few beech. When such areas are well developed they merge into the uneconomic woodland considered below, and are treated as such. At earlier stages they are difficult as the trees are not yet sufficiently developed to provide good overhead cover. The longer such areas can be left to themselves the better. The object of ground preparation here is to thin the scrub to the desirable density, and subsequently to introduce beech. Groups of ash, birch, and sycamore barely reaching 10 feet in height may often occur. These are best left to grow on and provide side shelter, for thinning and underplanting of such groups will involve much expensive weeding of coppice regrowth. Often,

ground preparation will consist of the clearance of groups of dogwood, privet, &c., leaving the ash, birch, and sycamore plots to serve as side shade, and leaving such individual specimens of these tree species as occur within the cleared groups to serve as partial overhead cover. Where soil conditions are good, some of the ash may produce useful stems, and sycamore is often a reliable species on thin soils. In any event, the birch, ash, and sycamore plots can be thinned and underplanted at a later stage, i.e. when they have grown enough to provide effective overhead cover.

Uneconomical woodland. These areas often provide ideal overhead cover for beech. The crop usually dominated by birch, ash, and sycamore is thinned to allow about 25 per cent. of direct daylight to the underplanted beech. The cover should be as regularly disposed as possible, avoiding large gaps in the canopy. In general oak and beech should not be left as part of the overhead cover. The former is likely to grow very coarse, whilst the latter will cast too dense a shade. If good oak are found they should be preserved, but beech should not be planted near to them. In some cases enough useful species will be found to give a satisfactory crop without having recourse to general underplanting. This is a rehabilitation problem outside the scope of the present paper.

If desired a shade-bearing conifer may be planted in mixture with the beech. Here the aim is to provide an early financial return, to supplement the overhead cover where this is inadequate, and possibly to provide a continuous nursing effect, i.e. beyond the stage when the beech has overtopped the hardwood nurse. Douglas fir, Western red cedar, and Lawson cypress are possible choices, but there are others worth considering such as *Abies grandis* and *Tsuga heterophylla*. *Fomes annosus* and *Armellaria mellea* may be a limiting factor in some soils to the long retention of such conifers.

Yew forest. The large-scale felling of yew wood is undesirable silviculturally, economically, and aesthetically. But it is not difficult to make small openings in the canopy, and often small open spaces exist within the wood. Both the pre-existing spaces and those made artificially can be group planted with pure beech. Needless to say, rabbits must be exterminated and this may necessitate 'brashing-up' the yew to allow of access. This form of planting is expensive and is best done gradually.

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OCCURRENCE OF ECTOTROPHIC AND ENDOTROPHIC MYCORRHIZAS IN FOREST TREES

By IDA LEVISOHN

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SUMMARY

A short paper noting on the uncertainty of the relationship between taxonomic position and the form of mycorrhiza and recording a recent case of double infection in Lawson cypress (*Chamaecyparis lawsoniana* Parl.) in the south of England.

FRANK'S (1) classification of mycorrhizas into ectotrophic and endotrophic forms is still accepted in botanical textbooks, and although the separation of these two types may sometimes appear rigid and inadequate (Rayner, 2; Harley 3), it is nevertheless generally convenient and informative. There are a number of lists available supplying the names of plants regularly affected by one or other of these two forms of mycorrhizal infection, but this classification into ectotrophic and endotrophic plants is useful only so long as comparison is made with typical examples of these types.

It has long been recognized (1) that while the endotrophic form is widely distributed among numerous plant species, the ectotrophic form seems to be restricted to certain forest trees and shrubs: the *Pinaceae*, *Fagus*, *Betula*, *Corylus*, *Quercus*, and many other members of the *Fagales* [presence of ectotrophic mycorrhizas in wild fruit-trees has been reported by Stahl (4) and described by Dominik (5)]. In forest trees, existence of a relationship between taxonomic position and the occurrence of one form of infection in preference to the other is still a matter of conjecture, and any attempt to group particular families or species into ectotrophic or endotrophic classes meets with difficulties.

By way of example may be cited the case of the *Salicaceae*. According to information collected by Kelley (6), many species of the genus *Populus* are endotrophic while ectendotrophic infection is reported by Melin (7) for *P. tremula* in Sweden. In Great Britain, all species of *Populus* (including *P. tremula*) examined so far have been found to be ectotrophic whatever the soil conditions under which they were grown. As regards the genus *Salix*, whose 'uncertain behaviour' was pointed out by Stahl (4), a large number of species are recorded as being endotrophic (Kelley, 6). Among the British material, however, irrespective of soil and situation, certain species have invariably shown ectotrophic infection, e.g. *S. Caprea*, *S. fragilis*, and *S. reticulata*, while certain other species, e.g. *S. babylonica* and *S. pentandra* were found to possess typical endotrophic mycorrhizas. Considering the scarcity of available data and lack of knowledge about the reaction of some of the species in their natural habitat, it is difficult to judge whether the types of infection encountered in the genera *Populus* and *Salix* are conditioned by external factors or whether taxonomic relationships are involved.

A detailed account of a rare case of ectotrophic infection occurring in a species generally regarded to be endotrophic, is given by Lihnell (8) who found ectotrophic and endotrophic mycorrhizas in different branches of the same Juniper (*Juniperus communis*) root.

A similar case of such 'double infection' has recently been discovered in Lawson cypress (*Chamaecyparis lawsoniana* Parl.), another member of the *Cupressaceae*, and, like Juniper, usually bearing endotrophic associations. The Lawson cypress tree affected by the two forms of mycorrhizal infections is growing in a heathland soil in the south of England. It is about 20 years old, had been in check for a number of years, and then started to grow vigorously as the result of mulching which was carried out 8 years ago. Some root material was collected in the present autumn (1953), and whilst large portions of the dense mat of roots which had developed in the mulch showed endotrophic infection of the kind characteristic of Lawson cypress, some few root branches carried a number of conspicuous nodular bodies; microscopic examination established that these were tuber-mycorrhizas of typical ectotrophic structure. The tubers, mostly sessile, are 2–5 mm. in diameter and consist of forking rootlets with a Hartig net and individual mantles of 60–100μ in diameter formed by septate hyphae, 2–5μ wide, pinkish in colour. An external zone of loose hyphae—identical with those forming the individual mantles—was observed to pack the short rootlets into nodular bodies a considerable number of which were found detached in the soil.

In recording the occurrence of an ectotrophic mycorrhizal association in Lawson cypress, it may be of interest to recall the results of certain earlier pot-experiments (Levisohn, 9) which demonstrated the effect on 2-year old Lawson cypress seedlings of introducing into the soil an ectotrophic mycelium in the form of pine mycorrhizas. At the time of examination, the inoculated cultures showed improved growth, but had not developed ectotrophic or any other root association. Observations on experiments designed in a similar way and carried out over longer periods or under special conditions, i.e. mulching, may possibly contribute to throw some light on the 'mycorrhizal elasticity'—or the 'uncertain behaviour'—of the root systems of certain forest trees.

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CORNISH WOOD-NAMES AND TREE-NAMES

By H. L. EDLIN

SUMMARY

Details are given of place-names derived from the names of woods, and of various kinds of trees, in the Cornish language, a Celtic tongue formerly spoken in the extreme south-west of England.

SINCE the appearance of my previous article on this subject (1), Mr. G. D. Kitchingman, the Forestry Commission librarian, has kindly drawn my attention to the book entitled *British and Foreign Trees and Shrubs in Cornwall*, by Edgar Thurston, published by the Cambridge University Press in 1930. This includes a section headed 'Evidence of Place Names of Woods in the Middle Ages', and another on 'Names of Trees in Cornish Place-Names'; while a third on 'Cornish Names of Trees and Shrubs' was contributed by R. Morton Nance.

As might be expected from the close similarity between the two languages, the Cornish words for trees and woods are usually very close to the Welsh. Thurston points out, however, that there exists a difference between east and west Cornish place-names. In east Cornwall, he says, where English first supplanted the Cornish language, the names are in their purer, if harsher form, which resembles the modern Welsh. Farther west, they have the softened sounds of later Cornish. For example, *coed*, Welsh for a wood, is represented by *cote* in east Cornwall, but by *coose* in the west. The wood-names and tree-names quoted by Thurston are summarized below:

AVALLEN. Apple. As at Nansavallan, vale of the apple-trees.

BANATHAL. Broom. As at Bonallack.

BEDOU or BEDHEWEN. Birch. As at Bissou and PENBETHAN, head of the birch wood.

COED. A wood. Not found unmodified, but gives rise to the following common variations: *coose*, *coj*, *cot*, *cote*, *coys*, *cot*, *cut*, *cutt*, *goose*, and *quite*. Place-names ending in *-goose*, such as Tregoose, village of the wood, are particularly frequent in Cornwall; Quethiock, an extreme variation, is from *coedioc*, the wooded place.

COLLEN or COLWIDHEN. Hazel. As at Nance-gollan, hazel valley.

DAR or DERWEN. Oak. As in Landurrow, Alterwen, Dumblederry wood, &c.

DRAENEN. Thorn. Commonly represented as *drinnick*—thorny.

GLASTANNEN. Alternative name for oak or holm oak. At Pons Glastannen—oak-tree bridge.

GWERN. Alder. Represented by *wern*, or *warn*, as at Penwarne.

GWYTH. Trees. Singulative form is *gwedhen*, a tree, while *gwedhenek* is an adjective meaning woody. Examples are Trengweath, Tresgwithen, and Carwithenack. The Welsh equivalents are *gwydd*, trees; *gwydden*, a tree; and *gwyddiau*, wooden.

HELYGEN. Willow. Plural *helyk*. As at Penhelligan and Penhellick—head of the willows.

KELINNEN. Holly. *Keleinic* means place of holly-trees. As at Kelynack.

KELLY. A grove, equivalent to Welsh *celli*. Found at Killiow, &c.

KERDHEN. Rowan. As at Kerthen.

LLANERCH. Welsh for clearing or glade, is found in Cornwall at several places named Lanner.

LLWYN. Welsh for a grove, is rendered as *loan*, *lowe*, *long*, *lan*, or *long*. As at Nanslowen, valley of the grove.

PERTH. Welsh for a bush or brake, occurs in Cornwall in such names as Penberthy, head of the bushes.

PRYSGL. Welsh for copse or thicket, plural *prysgau*, is found in Cornwall at Priske.

ONNEN. Welsh for ash-tree. Rendered in Cornish as *enwedhen*, plural *enwyth*. Trenwith, near St. Ives, is from Trunwith, village of the ash-trees.

SCAWEN. Elder. As at Goon Scawen, elder-tree down.

Thurston remarks on the frequency with which place-names derived from trees and woods are found in Cornwall, sometimes in places that are now treeless.

The tree-names in Nance's glossary are, for the most part, like those found in Welsh, with minor spelling differences. Attention may be drawn to the Cornish word *sybwedhen*, plural *sybwyth*, also rendered as *sibuit* and *saban*, which has a Welsh equivalent *sybwydden*, plural *sybwydd*. It means pine or fir, and is apparently related to the French *sapin*. It is known that the Scots pine was once native to the south of Britain, though how far it survived or became extinct there is often a matter of dispute. The fact that both the Welsh and the Cornish have a name (and apparently an indigenous name) for it, suggests that it was encountered during the Celtic invasions, which took place around 500 B.C.

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REVIEWS

Woodland Management. By W. E. Hiley. Faber & Faber Ltd., 24 Russell Square, London, W.C. 1. 1954. Pp. 463 with 58 plates and 8 figures in the text. Price 63*s.* net.

Review by H. G. Champion

FROM the active and prominent part Mr. Hiley has taken for many years in advancing British forestry, his views on the main issues are widely known, but we have all been looking forward to a connected account in book form. We now have the masterly exposition which we have been expecting, in *Woodland Management*, published by Faber & Faber Ltd. It is to be feared that the price of 63*s.* will put it beyond the reach of the impecunious student—and that includes today both young and old—but it is unquestionably a first-class production, a credit to the publisher as well as to the author. We readily agree with the jacket that all forest libraries, big and small, private and public, will have to get it and will get their money's worth. Whilst we can hardly imagine that H.M. Forestry Commission will implement the recommendation appearing on the publishers' notice that their officers should be 'required' to read it, we doubt whether many of them will miss an opportunity to do so and if they do miss it, their loss will be considerable. Mr. Hiley, as quoted both on this notice and on the dust jacket, has been shocked by the discovery that our University courses in forestry (to which we believe he was not himself fully subjected, as his earlier career was in the mycological field and lead to his excellent work on the diseases of larch) did not cover the needs of a practical forester. We in turn are shocked to learn that with all his academic experience and continued contacts, he can even now confuse the objectives of a University and a Technical School respectively. Had it been known what the future had in store for him, he should evidently, while teaching forest economics at Oxford, have studied forestry at Parkend even though the instructors there might have trained at one of these inadequate University schools: for the immediate purpose of running a small area of woodland in this country, this very probably would be the best training.

Turning to the content of the book, we have 25 chapters grouped in four parts dealing respectively with organization, production, maintenance, and administration of woodlands. Many of these chapters are among the best expositions of the topics dealt with, that are known to the reviewer, whether Mr. Hiley is marshalling for us well known and agreed material or whether he is presenting material and views conspicuously his own.

We may refer to the sections on contract work, employment, pruning 'method of control', and particularly on legal restrictions (Chap. 22) and on finance generally as examples. The statistical data, many drawn from his own experience at Dartington Hall but supplemented by others from the Forestry Commission or private owners, are a most valuable feature—and at this point, we must commend the 58 excellently selected, taken and reproduced photographs included with the text. We like and endorse the warnings given from time to time against being drawn by over enthusiasm into undertaking more than staff or management on a given estate can cope with—as against the setting up of an estate sawmill (p. 43), or the introduction of the selection system (p. 309); and on the other hand, the encouragement of road construction (p. 53) and thinning rather ahead of momentarily essential needs (p. 261).

Of course, we do not look in vain for a lengthy treatment of thinning with the dice

loaded in favour of the heaviest conceivable. In fact, the long-accepted dictum for ideal thinning treatment, viz. 'light and often', is to be replaced by 'heavy and often' (p. 226). It may be questioned whether Mr. Hiley is always fair to those he criticizes though he usually covers himself with a little proviso such as 'at any rate in a fast-growing area such as I was working in' (p. 219) and often illustrates a general point by quoting the extreme case of Japanese larch. Many readers are likely to think that his recommendations may well be right for the favourable conditions of Devonshire, but are they valid for the drier regions and poorer soils? Again, in rejecting descriptive criteria for carrying out a thinning, he loses sight of the probability, if not the accepted fact, that for some species and conditions crown thinnings are the most suitable and they cannot easily be prescribed numerically. The reviewer does not recall a published yield table which omits to show number of stems per unit area and the charge against our predecessors of woolliness in this matter (p. 248) is quite unjustified. What has been done for us by the succession of pioneers quoted is to tabulate how crops have in fact grown with different numbers of stems at stated ages and provide the statistical basis for the further step he now wants us to take. Again, the computation made on p. 231 to add weight to the case built up against Light Thinning (even to the extent of leaded type for figures which by an unfortunate misprint have lost a decimal point) is questionable. Readers will find this section, unlike practically all the rest of the book, difficult to follow, and a check against the original authorities quoted will not clear things up—nor does another slip or misprint at the bottom of p. 230, though these two are almost the only misprints detected in the whole book. Incidentally, has anyone seen 3,000 European larch established in an acre of plantation (p. 260)?

We all have our own views on thinnings and it must be agreed that opinion and practice tend to run ahead of research results that will meet modern statistical criteria. It is to be regretted that the older experiments which have been going long enough to give clear results are too few for the great range of species and sites we have to deal with, and have too rarely fulfilled the sound research principle that the range of treatments applied (in this case intensity of thinning) should go well beyond the probable optimum. We are glad it was possible to include a theoretical consideration and such excellent photos of the famous Bowmont Thinning Experiment which is in several respects the finest thing of its kind in the world. A comment (p. 219) on thinning practice that is somewhat surprising is that a forester should know *after completing a thinning* (our italics) when it will be necessary to thin again. Surely, *before and whilst making a thinning*, the practical forester should have in mind the period that is likely to elapse before he will be able to get in again. This is perhaps a minor instance of an attitude that keeps on creeping in to the general presentation, that the manager will be able to keep all his stands under close observation all the time, and come in and carry out desirable operations the moment they become desirable. This is quite out of the question in big-scale operations and is often impracticable even on a smaller scale where limitations of labour, transport, and even markets are influential.

There is a serious probability that some of the recommendations given, sound though they may be under the right conditions, are dangerous in that they may well be acted on without the general context in which they are made or without regard to the not over conspicuous provisos accompanying them. Thus the suggestions for heavier felling on p. 52, selective logging on p. 111, and elasticity in working plans (p. 369) should all result in improving the forest if carried out by a really skilled manager, but can produce chaos if done by anyone else. Again, the remarks on the influence of width of annual rings on uses, demand, and price of coniferous timber on pp. 238–9 and pp. 289, 290 are not easily reconciled with the existing position in, for example, the Jura forests, where narrow ringed timber of good quality commands relative prices that make nonsense of some of the figures

of Table 46. The great extension of the use of softwood veneers has not been taken sufficiently into account.

Another section one looks at with special interest is that on the application of the selection system to British conditions. A bias in favour of it shows through in one or two places but the point is conceded that at present only the experimental approach can be recommended. The connected notes on two storied high forest are interesting but might have been carried further.

Turning to the Management Plan (Chap. 2) and Working Plans (Chap. 21), we feel that Mr. Hiley is attempting to make the British foresters' nomenclature even worse confounded than the Dedication Scheme has made it. Afraid, perhaps, that the term 'Working Plan' would convey the impression of something elaborate beyond the capacity of the average private owner, the Forestry Commission appears to have thought that the substitution of a word with a Latin root instead of an Old English one would be more readily accepted and so adopted 'Plan of Operations' which by long prior usage implies in professional circles a statement, usually tabulated, of the detailed operations to be carried out under the more general prescriptions of a Working Plan. If Mr. Hiley's 'Management Plan' were what he describes it as on p. 367, no one would object—rather the reverse—but as he sets it out in detail in Chap. 2, it must include essential parts of a working plan in the established sense. To the reviewer, there seem to be two alternatives open to us. Either we decide first what we think we ought to do in our woods; then consider the labour, supervision, equipment, and finance needed to do it; and finally adjust the desirable with the practicable. Or we start at the other end, and from the provision that we happen to have or can get at the moment, of the four essentials just mentioned, we go to the woods and see how best we can apply them. Can it be doubted which is the sounder procedure?—or that Mr. Hiley's Management Plan should be a section in the latter part of a Forest or Woodland working plan which may well be very short and simple, but should be comprehensive and should take into account both short term (for the Plan of Operations) and long term aspects—objects of management and steps to work towards them. The two aspects are so closely interrelated that they cannot be divorced from each other. One can agree with Mr. Hiley that a newly graduated student should be able to draw up a plan of operations with a good working plan in his hand in the woods, but if he attempts the task without it, he can merely tabulate some desirable silvicultural measures to be carried out with no regard to forest-management ideals and an experienced forester with no school training could do it better.

Reference has been made above to the excellence of the printers' and publishers' work throughout the volume, though not everyone will like the 10 inch × 6 inch size, nor the colour. On the editing side, we have noted the rarity of misprints, but the absence of page references to the diagrams when they are quoted in the text is annoying. We would advise readers to save themselves considerable annoyance when they will be consulting the book later, by pencilling the references in each time they hunt one up. It may be queried whether it is unfortunate or a good thing that the figures for the Planting and Maintenance grants (pp. 396–7) are already out of date. We have also the detailed Census data (p. 390) since the book was written.

In conclusion, we may quote one or two extracts which will appeal to and be remembered by many of us. We particularly like '. . . designing a form of plan which will put a backbone into management but which will not be a straight jacket which strangles the enterprise of a progressive forester' (p. 367); also 'we learn by experience that the axe and the saw are more important silvicultural tools than the mattock and the planting spade' (pp. 103–4). And again, 'the cultivation of hazel coppice is probably the most important contribution which England has made to the history of forest management' (p. 168). If some of

the above comments appear hypercritical, they are intended to be constructive and are entirely compatible with the reviewer's opinion that this is a most valuable and stimulating book which no one but Mr. Hiley could have written, and a book which will perhaps be viewed in the future as marking an important stage in the evolution of British forestry.

Studies on British Beechwoods. By J. M. B. Brown. Forestry Commission Bulletin, No. 20. 1953. Her Majesty's Stationery Office. Pp. 100 with 28 full-page photographs and diagrams. Price 12*s*. 6*d*.

Review by W. E. Jones

THIS bulletin is of interest from several points of view. As summarizing the results of the first major undertaking of the ecological section of the Commission Research staff at Alice Holt we hope that it heralds more work of equal quality. As the silviculture of beech is of considerable topical importance, the bulletin will be welcomed by many who rightly look to the Commission for some guidance in this direction, for not only does it present the results of the Commission's own investigations into the growth of beech in Britain, but it assembles more miscellaneous information on the biology of beech from foreign sources than has previously been available in any convenient summarized form in the English language.

Part I of the bulletin is little more than a general introduction in which one or two of the salient features of the biology of beech such as its distribution in Europe and in Britain and its history in Britain are reviewed. Parts II and III, which together form more than 60 pages, are devoted mainly to a review of the information collected by a survey of British beech woods for which Mr. Brown was responsible. In this survey about 200 stands from all parts of the country where crops exist were examined and their age, quality, condition, and the site factors recorded for each. This basic information so far as it relates to the physical properties of the site and to the increment of the beech is reproduced in summarized form in tables in the appendices. Records of this kind can be extremely valuable for those who know how to use them and they are well worth publishing for their own sake; there is no better way of deciding what quality of crop one is justified in expecting on a given site than to find out what has happened on comparable sites, and conversely comparison with such records may reveal failure of a crop to come up to expectation and so point to errors of silviculture as possible explanations of the deficiency. The survey is especially valuable for the amount of information it gives on the performance of beech outside its supposed native range.

Most of part II is devoted to a review of the mature crops and to the relation between quality of stand and site factors. The stands are classified according to substratum into those on chalk, those on the older limestones, those on non-calcareous loams (clay-with-flints and the deeper drifts over chalk are included here), and those on sands. It is obvious from the age-height graphs reproduced in the appendix that the range of qualities in each of these four groups is identical so that though this classification may be important from a silvicultural point of view it is of little value from a mensurational point of view, and variations of soil within these groups of variations of climate must be more influential than the gross differences between them in determining quality. Perhaps from the scientific point of view the only completely satisfactory way of studying the relative importance of the various environmental factors on height growth is by the use of statistical methods in which regressions are calculated. The disadvantage of this procedure, apart from the computational labour which it entails and the necessity for expressing environmental factors numerically,

is that the results are presented in the form of a series of equations which are incomprehensible to the lay-man. Part III, devoted to the wider aspects of the silviculture of beech, and in particular to its establishment by natural and artificial regeneration, will perhaps prove to be the section of most general interest.

Throughout the whole bulletin there are numerous observations which are of interest or which provide food for thought—for example, the good performance of beech on old woodland sites, the relatively slight reduction in the height growth of young beech brought about by reducing the light intensity to as little as a fifth of 'full' daylight, and the observations on insect attack to leading shoots and the formation of lammas shoots. It is only possible to comment on a few of the many points of interest here.

In discussing the natural distribution of beech in Britain mention is made of 'suggestive' place-names such as Buxton (Derbyshire) and Bickleigh (Devon) outside what is usually accepted as the native range of beech. The possibility of using evidence from place-names to indicate former distribution of trees is very attractive, but in practice great caution is needed. What could be more natural than to assume that Buckholt, for example, means beechholt? Yet early forms of the word show that in fact it means 'book-hold' (a form of tenure). What with books, bucks, and Saxon gentlemen called Bucca and Bica there are plenty of possible origins for names suggestive of beech, and the early forms given in Ekwall's *Dictionary of English Place Names* make it clear that neither of the examples suggested by Mr. Brown derive from beech. Indeed such names seem to be rare; I can trace none in the two Chiltern counties of Oxford and Buckingham, though outside the present area of indigenous beech there appear to be one or two examples in Hereford, Worcester, Warwick, Essex, a doubtful example in Northants, one in Cheshire, one in the West Riding, while Ekwall cites a very unconvincing example from Northumberland. Mr. Guile informs me that place-names deriving from the Welsh word for beech exist in the Grwyne valley in Breconshire, and there seems to be very good reason for accepting beech as indigenous throughout south-eastern Wales. Curiously enough Mr. Brown makes no mention of beech in the New Forest where many of the unenclosed woods are now virtually pure beech; there seems to be no reason whatever to doubt its being indigenous there, and its pollen occurs in peats there earlier than in the rest of England.

In discussing the climatic range of beech Mr. Brown points out that in Bavaria its upper altitudinal limit has been shown to coincide approximately with the mean July isotherm for 13° C. and points out that almost the whole of the British Isles lies within this limit. This is perfectly true, but from analogy with the mean July temperatures at the altitudinal and latitudinal limits of trees we might expect the boundary of beech to coincide with at least 14° and perhaps as much as 15 or 15·5° C. in the oceanic climate of this country rather than with the 13° isotherm which it follows in continental Europe. Judged on this basis, beech must be nearing its climatic limits over much of Scotland.

Mr. Brown points out that beech nuts lying on the surface of the ground may be killed by severe winter frosts; beech nuts are less easily injured in this way than are acorns, but unpublished experiments by Mr. G. Gray at the Imperial Forestry Institute have shown that 3 hours at temperatures less than about 21° F. (61° C.) are fatal.

After reviewing the information on rates of growth, Mr. Brown decides that a rotation of 140 years is likely to be enough to produce trees which are 18 in. (45 cm.) diameter and that in the south of England the rotation may prove a good deal less; 'only on shallow rendzina soils or on dry exposed hillsides will it be necessary to extend the rotation to 140 years.' It is interesting to compare this with continental practice. In some French forests where conditions are in general more favourable than in south England, rotations of about this length are in force. At Lyons la Forêt it proved necessary to lengthen the rotation from 150 to

180 years, but this was in order to produce trees of 60 cm. diam., and it also has to allow for relatively slow natural regeneration. If it is assumed that the rate of diameter increment is uniform throughout life, a diameter of 60 cm. at an age of 180 corresponds to a diameter of 45 cm. at an age of 135 years. On really shallow rendzinas on chalk the beech is short-lived and the question arises as to whether it would remain healthy for 140 years.

The absence of bramble in the Scottish beech woods is—as Mr. Brown cautiously hints—doubtless a consequence of the fact that the *Rubi* which are such aggressive inhabitants of English woodlands are in fact lowland and southern species which become rare even at altitudes approaching a thousand feet in the south of England.

The observations on the establishment of beech on chalk downland and in derelict woodland are of great interest, and there is a scholarly discussion on the effects of the several environmental factors concerned, such as frost, light intensity, humidity of air and soil, yet the discussion leaves a slight feeling of bewilderment, largely I think, because it is so often in general terms and there is no evidence as to the relative importance of the various factors, not as to their importance for beech in particular as compared with any other plant. I make this criticism with great diffidence, for I am painfully aware on the one hand of the great difficulty of making precise statements about the relative importance of environmental factors, and on the other hand the danger of assuming without investigation that particular factors are of negligible importance. The interaction of environmental factors is of course so complex that it would need a far more elaborate investigation than this simple survey to measure their relative importance with any degree of precision. Beech may, for example, fail on a shallow chalk soil where it has been severely frosted. Doubtless in the absence of frost the beech would have survived, but it might also have survived if the soils had been deeper so that growth was faster. While it may not be possible to deepen the soil in practice, it might be possible to improve it to such an extent by removing competition from surrounding vegetation that the rate of growth of the beech is increased and survival assured despite the frost. In such conditions we cannot speak of either frost or drought or shallow soil or competing vegetation as the cause of failure; all are contributary. It is for the ecologist to disentangle the relevant environmental factors, to study their mode of action and assess their relative importance; it is then for the silviculturist to decide which factors it is most expedient to modify so as to improve the environment. It is perhaps the lack of emphasis on the relative importance of the factors of practical importance that constitutes the chief weakness of the discussion.

It is always very difficult to distinguish between sets of phenomena which are cause and effect and sets which originate from a common cause. Some of the observations which are quoted as demonstrating a particular influence are open to the alternative explanation. On p. 43 the very striking instance of the correlation between depth of soil and growth of 21–22-year-old beech on chalk downland in Compartment 1 of Crawley Forest is cited. In fact the figures from Compartments 1 and 4 at Crawley given in Appendix VIA reveal a remarkably close linear relationship between the height of the beech and the depth of loam above chalk. The two plots from Compartment 7 at Crawley and plot No. 285 from Buriton show almost exactly the same regression of height on depth of soil, except that for corresponding depths of soil the height is about 8 feet less (the beech are only a year younger). Now it appears from the records that the principal difference between these two groups of plots is that the first group is on old arable land, the second group on uncultivated downland. When therefore the two plots in Compartment 7 at Crawley are quoted as showing the beneficial influence of shelter from scrub (p. 45) it is at least equally likely that the beech has grown better for the same reason that the scrub has persisted, namely because the soil is deeper. It is suggested (p. 41) that the beneficial effect of ploughing is likely to be

slight, but here it seems to have made a difference of about 7 feet in 21 years—not inconsiderable for trees that average 10 feet total height: it is, moreover, very doubtful whether in practice more water will ever be lost by evaporation from a bare surface soil than would be transpired from the vegetation covering the same soil—usually the situation is the reverse.

Regarding the effect of beech on the soil Mr. Brown sides very definitely with the view which has spread mainly from Scandinavia that beech litter can form raw humus and so initiate the deterioration of the soil, and that the danger of this happening is very real. He also appears to assume in common with many continental ecologists that leaching of the soil is an inevitable result of the growth of beech, and that the mature soil of the beech forest will therefore be a Brown Forest Soil, perhaps degraded. To my mind these views, though doubtless based on elements of truth, can easily be pushed too far by stressing the few concepts which it has been possible to build up from the clearly established principles and ignoring the many complicating factors which we do not understand. But as Mr. Brown rightly says they are vexed questions; one should be critical even in assuming that the formation of more is necessarily an evil (especially when humus on chalk soil is to be included) under that definition.

One other question comes to mind: for whom is the bulletin intended? If for the scientifically trained forester, then some of the material, such as description of representative soil profiles is scarcely necessary, while if for the layman, at the very least a glossary of scientific terms would be desirable. Perfection is something which is very difficult to attain and it is too easy to be carping in criticism. Whatever I or other reviewers may say, Mr. Brown's survey of British Beechwoods has been a very useful piece of work, and the bulletin is well written, beautifully adorned with photographs, and full of meat.

Revised Yield Tables for Conifers in Great Britain. By F. C. Hummel and J. Christie. Forestry Commission, Forest Record, No. 24. 1953. Her Majesty's Stationery Office. Price 1*s.* 3*d.*

Review by W. E. Hiley

THE publication of new yield tables is an event of major importance in British forestry and, though we await with lively expectancy the early appearance of a full Bulletin on the methods used in constructing them, we are grateful to the Commission for issuing these tables in a handy form. There are two introductory pages which point out the main differences between these tables and those which were published earlier, and these are followed by age-height graphs and tables for the seven species which are most commonly grown in Britain.

The reliability of the tables is enhanced by their having been constructed entirely from permanent sample plot records, and the use of over bark measurements for volumes and form factors will be welcomed by practical foresters. As before, the basis of quality class is the height at 50 years but, instead of the average height of all the trees, the top height, i.e. the average height of the hundred largest trees per acre, is used as the criterion of quality. This is an improvement because it helps to remove the uncertainty caused by variations in thinning, and when estimating the quality class of a particular plantation it is easier to measure the height of a few dominants than to compute the average height of the stand. It means, however, that the new quality classes are not exactly comparable with those in the older tables as the top height may be anything up to 4 feet higher than the average height.

For this reason the new quality classes are somewhat lower than the old classes with the same denominations, and it has become necessary to introduce a new and higher quality class for four of the species: Scots pine, Corsican pine, Sitka spruce, and Japanese larch. So the first quality class for all these species is some 7 or 8 feet higher at 50 years than the old first quality and, when the new Bulletin arrives, we shall hope to learn the proportion of the sample plots which are included in these new top classes. No distinction is now drawn between Scots pine in England and Scotland.

In the old tables the interval between thinnings was assumed to be 5 years for all species and all ages. We now have intervals varying from 2 to 10 years according to the thinning period which is found to be customary and, although this is an endeavour to be realistic, it makes calculation and comparison more difficult. A heavier thinning régime has been followed with all species and it appears to be exactly in accordance with the numerical tables in the second edition of the Commission's pamphlet, *The Thinning of Plantations*.

The tables have been enlarged by the inclusion of columns for the quarter girth of thinnings, for total yield, current annual increment and mean annual increment, figures which are invaluable for the forest statistician or economist. But the most interesting innovation is the introduction of figures for the mean height and quarter girth of the 100 largest trees at all ages. This enables one to calculate the average thickness of the annual rings put on in each thinning period and thereby to guage the final structure of the dominant trees. In all species except Norway spruce the annual ring thickness falls to a low figure at the end of the table which suggests that the later thinnings are unduly light and that by heavier thinning towards the end of the rotation it might be possible to grow larger trees without loss of quality. With some species the ring widths throughout appear unnecessarily narrow, the most serious culprit being European larch which in its first 75 years has an *average* of 14, 17, and 21 rings to the inch for 1st, 2nd, and 3rd quality. Surely we can do better than this!

This new means of visualizing the probable results of a thinning régime opens up an important field for research; and for this and for many other reasons the tables will be invaluable for British forestry; we are greatly indebted to the authors for the care and ingenuity they have exercised in constructing them.

'Recherches Théoriques et Pratiques sur la Répartition en Quantité et en Qualité de la Lumière dans le milieu Forestier; Influence sur la Végétation.' By Louis Roussel. *Annales de l'École Nationale des Eaux et Forêts et de la Station de Recherches et Expériences*. Tome xiii, fascicule 2, 1953. 14 Rue Girardet, Nancy. France.

Review by W. A. Fairbairn

THE author, an outstanding worker in the field of photology, has already contributed a series of valuable papers to the *Bulletin de la Société Forestière de Franche-Comté*. This paper, which contains 99 pages in all, covers a wider field, dealing in three major parts, first with research work, past and present, secondly, with theoretical considerations in light measurements and lastly with the authors' research work in coniferous stands in the French Jura. Early work and literature are reviewed and the bibliography, one of the fullest which has been published, includes references from American and British authors up to 1940. The paper includes excellent photographs, useful diagrams, and drawings of anatomical microscopic sections which show cell reaction to different intensities of radiation. There is a

3-page summary in German and in English; the latter, for its length, does not do justice to the paper itself.

Part I, describing research past and present, deals in turn with the reactions to light of the human eye, which is not an efficient measurer of radiation. Photochemical methods and the use of photographic light-measuring paper are next reviewed. In this section the important conclusion is recorded that the measurement of diffuse light gives more constant results than that of direct sunlight.

Photomet rs are next mentioned, including one used by Bouguer as early as 1729 and another, more recently used by Dr. Knuchel in 1914, one of the earliest and most interesting uses of the photometer in forestry. The author then discusses the photo-electric cell (or photopile), including the photometer, used in photography, which has the advantage of being relatively inexpensive, light, and therefore easy to handle.

The photopile, it is stated, is distinctive in that it is dependent upon the electric current generated solely by the amount of radiation which is received. Photopiles were used, amongst others, by Weaver and Clements prior to 1929, by Wagner in 1938, and by Dr. Nægeli before 1940 who, incidentally, used light filters on each instrument which did not seem to give rise to errors, the results, as Roussel records, being acceptable.

Actinometers and their use are described in the penultimate section of Part I; they cover types of apparatus which are designed to measure total radiation, the combination of direct sunlight and of diffused light from the sky and clouds. Four different types of actinometers are mentioned, which make use of thermometers, volatile liquid, platinum wires, and the thermo-electric pile respectively. The Bellani actinometer (which belongs to the second type) is one of those more widely used. Six of these were employed by A. Oudin in 1929, one being used in the open, the others in stands of varying types; this is believed to be the first time actinometers were used in France for measurement in forest stands. It is also recorded that other studies have been made in regard to germination, growth of plants, of leaves and needles, and in connexion with root development.

The author concludes the first part of this paper by pointing out that in light measurement there has been, and is, a great diversity of procedure, so that a wide range of results has been obtained; he trusts (and this can scarcely be over-stressed), that in order to obtain comparable results, a certain number or methods of measuring radiation should seriously be studied, and that the most satisfactory method be recommended to all engaged in this very important work.

The second part of the paper deals in considerable detail with theoretical considerations in connexion with photometry in the forest. The writer reviews the source of radiation, and the screening of light; he then discusses the effects of cloud conditions and of the cloudless sky. Gaps in the forest are then considered with reference to direct and diffuse radiation. Formulae are given for the two sets of conditions. Two interesting and instructive diagrams are included, showing the trajectory of the sun's rays at the winter and at the summer solstice.

These considerations, as the author states, make the measurement of radiation extremely complicated; with, however, the help of the formulae evolved, it is possible to obtain the relative radiation values in gaps of simple geometrical form; using 'the total illumination circle', it is possible to ascertain the relative radiation by diffused light (from the sky) and the relative amount from direct light (from the sun).

In this part the author correctly stresses the fundamental meaning of the word 'light' in instrumental comparison, as referring to visible light, and of 'radiation' which should be applied to total radiation. He states that eminent specialists in photometry have not always escaped misuse of these terms which has led to a certain confusion; he would favour the old

terms of 'brilliance' and 'bougie' which since 1948 should be, he states, 'luminance' and 'candella'. It seems desirable that the meaning of the words 'light' and 'radiation' should be standardized by English-speaking workers.

The third part of the paper deals with personal research by the author, a record of much sound work; this is described under first, the methods of taking spot or instantaneous readings, and secondly, methods of taking continuous or accumulated measurements. In the former the author discusses photo-electric cell measurements of the relative light in the open and in forest conditions; the formula $Er=\frac{K}{N}$ is given, where Er is the relative light, K a constant (20 in the case of spruce and silver fir) and N for the number of stems per hectare. It is interesting to note that the light required for natural regeneration of spruce and silver fir is 1–5 per cent.; for the period of growth, when more light is needed, 10–15 per cent. is required for silver fir and 25–30 per cent. for spruce. The author feels that the photometer will come to be a valuable adjunct to the forester. Working methods are also reviewed and Fig. 19 shows a method of taking radiation measurements in an area of 10 metres square; 39 readings were taken at 1-metre intervals round the perimeter and 25 across the diagonals. These can be taken rapidly, but the reviewer has found that fuller data are obtained almost as quickly, by taking 100 readings on the chequer-board plan wherein a fuller pattern of the radiation in the plot can be obtained.

The author points out that the effect of radiation on growth is readily observed and measured, as in the case of the annual shoot, its length, diameter, and the fresh and dry weight; anatomical differences too can be observed and measured microscopically. A 'brillancemètre' or spectro-photometer has been used to assess the percentage of total reflection from the leaves of different forest species; this was found to be quite considerable; there is 10–15 per cent. of the total reflexion in the case of spruce, 24–28 per cent. for early foliage of beech, and 20–24 per cent. for beech in full leaf; it is remarked that in general the sombre coniferous needles absorb a higher proportion of radiation than leaves of the hardwood species. These are interesting observations, since the amount of light passing through the leaves themselves (such as young beech, silver birch, aspen, and so on) and the reflexion of light in a tree canopy, are not generally appreciated.

The author stresses the value of the actinometer over the photopile. The former giving not only continuous, or accumulated, measurements, but a record of the total radiation; the value of the Bellani actinometer is stressed; the reviewer feels that it might be considered for general use by research workers in this field.

Extensive data have been obtained from actinometers placed in the open and in forest stands; a series of five Montsouris actinometers were used under different media, in a mixed coniferous forest, from 1st May to 30th September 1951, and a most useful diagram (Fig. 21) records, at weekly intervals, the variation in the related radiation and of the angle of the sun above the horizon.

The effect on light, of felling in a forest stand is generally appreciated. Roussel usefully records, however, that in certain forest stands where 36 per cent. of the number of stems and 23·5 per cent. of the total volume were removed, actinometers placed in the untouched stand, on the edge of the felling area and in the centre of the felling area, recorded before felling 4·25, 7·61, and 20·97 per cent. of relative radiation, after felling these measurements were 18·0, 18·6, and 22·1 per cent. Another interesting series of measurements show that in the first four of five different areas with relative radiation of 1·22, 3·28, 4·25, 7·61, and 20·97 per cent., natural regeneration of Abies alba was 95 per cent. and that of Picea excelsa 5 per cent.; in the fifth, a long established gap, that of Abies was 5 per cent. and of Picea 95 per cent. Photographs of the third, fourth, and fifth plots accompany the text, and show interesting comparisons between the plots.

The paper terminates with a summing up which is interesting, illuminating, and should be instructive to all workers in this field. The author points out how difficult it is to draw precise conclusions in such a vast domain as vegetational physiology, so many factors come into play which make the growth of forest-tree species infinitely complex and, as the author records, leads naturally to concluding the paper with a large interrogation mark. The value of light measurements in connexion with silviculture is very rightly stressed and he recommends their use in species (other than those on which he has worked), such as oak, larch, and pine, while he points out that shadebearers, such as beech and silver fir, would benefit from accurate figures concerning their minimum demands. The usefulness of light measurement in forest management is also stressed, especially when it is linked with the encouragement of natural regeneration in both high forest and in selection forest, where it is desirable to have groups with sufficient light for the normal growth of the young regeneration.

The author finishes on a philosophical note, pointing out that the personal judgement or assessments of the forester are necessarily limited, that science is advancing, that it is desirable to appreciate the results obtained, to use more precise instruments in such a way as to get higher and better production from the forest, thus contributing to the forester's efficiency, and to the increase of the well-being of humanity.

This is the most comprehensive of M. Roussel's useful series of papers and he has made a most effective and valuable contribution in this field of study. It is a publication which will increase the interest in the measurement of radiation and influence the methods employed by the various research workers, to whom it will be of considerable value. The paper should also encourage new workers in this field; it will do much towards obtaining more uniformity, greater co-operation and co-ordination in this most important field of research.

The Forester's Handbook. By H. L. Edlin. Thames and Hudson, 244 High Holborn, London, W.C. 1. 1953. Pp. 395. 31 photogravure plates and 12 line drawings. Price 35*s*.

Review by F. K. Makins

FOR many years there has been an urgent need for a concise handbook, preferably a pocketbook, giving basic information for the use of British foresters. It is not so much a textbook of forestry that is needed as a compendium of facts and conclusions on which a practising forester can rely without constantly referring to a number of separate volumes. Except in one important particular *The Forester's Handbook* by H. L. Edlin provides such a compendium. It covers everything a practising forester needs to know, a difficult thing to do within the covers of a single book; it is written in simple and clear language; and it cleverly avoids controversial matters which might have obscured its main object.

Not everyone will agree with all the statements made in Chapter XV on marketing. For example, when dealing with contracts for the sale of standing or felled timber it is too much to infer that the buyer's measurements on which he calculates the feller's piece rates are any guide to the merchantable volume, or that the buyer can be held responsible for every kind of incidental damage. Again, the time for completion of felling and removal must allow for unforeseen circumstances beyond the control of the buyer. The disposal of lop-and-top, too, is one of several forestry operations which owners cannot always expect the buyer of the timber to do for them free of charge. It would have added to the value of

this chapter if some specimen forms of contract could have been appended, not only for sales but for contract work generally.

Chapter XX on management and plans of operations is based inevitably on the dedication proposals, but is an improvement on anything seen before, particularly that part of it dealing with objects of management, which should serve as a model for all private estates. Mr. Edlin's advice that 'the amount of work prescribed must, of course, be in keeping with the estates resources of capital and labour' should be hung up in every Conservator's office.

The important particular in which the book falls short of requirements already referred to is its size and cost. Had it been printed in smaller type on thinner paper and the photogravure plates omitted it could have been made portable and cheap enough for general issue, whereas it is now too bulky and expensive to go far from the library shelf. None the less, the author has done the practice of forestry in Britain a great service and the demand should be great enough to justify a cheap pocketbook edition.

Mushrooms and Toadstools. By JOHN RAMSBOTTOM. Collins, 14 St. James's Place, London, 1953. New Naturalist Series, No. 7. Pp. 306, 84 colour and 58 black and white photographs. Price 30*s*.

Review by C. G. DOBBS

ALTHOUGH this delightful book is intended mainly for the general naturalist-minded public, there are certain chapters which are of special interest to those concerned with forestry. The author, well known until his recent retirement as Keeper of Botany at the British Museum, writes with unique experience and authority, and has given us something more than a popular introduction to the fungi. He has somehow achieved a book which is equally fascinating to the professional mycologist and the complete neophyte. The life of trees is so mixed up with the fungal kingdom in all its multifarious activities, as symbionts, parasites, wood- and litter-decomposers and soil-inhabiters, that a great deal more of the book than the chapters referred to is relevant to forestry; and those parts which do not seem to have any such relevance, such as the historical chapter, and those on poisonous and edible fungi, mushroom growing, fairy rings, and the very competent account of penicillin, are themselves of great general and intrinsic interest.

The chapter (No. 18) on 'Mycorrhiza and Other Fungal Associations' is more than a summary of what is known on this subject. It brings to bear the judgement and observation of a naturalist with an unrivalled knowledge of fungi in the field, a viewpoint on this complex and controversial matter which is greatly needed and seldom encountered. Certain facts here presented, such as, for instance, the occasional appearance of fruit bodies of known mycorrhizal species in the absence of any host tree, are not usually mentioned in the more academic works. The following chapter is unique, and presents for the first time an ecological treatment of the fungi of woodlands, together with lists of general woodland fungi, and of fungi characteristic of pine-woods, deciduous woods, birch- beech- and oak-woods, as well as of fungi on trunks and stumps and on charcoal. It is unfortunate that this valuable chapter had to be drastically cut down, as indeed did the whole book before it could be fitted into the normal scope of the New Naturalist Series. It is much to be hoped that the additional material, especially on the undeveloped field of fungal ecology, will soon be made available in published form.

Chapter 20, on truffles, reminds us of an old forest industry which flourished for centuries in the south of England, but has now quite disappeared owing to the breaking up of the old estates, the changing ownership, and the felling of trees, though there is still no reason

to suppose that the truffles are not there to be found by those who know how to find them. The chapters on stink-horns, puff-balls, and earth-stars, and bird's nest fungi, give a graphic account of these odd and attractive organisms such as will not be found elsewhere; and indeed the whole book is full of curious and interesting and characteristic touches and historical references which no one else but Dr. Ramsbottom among those now writing in biological science could have produced, and which have the effect of moulding together the picture presented to the reader and giving it depth in time as well as space.

Although the book is a study of the activities of fungi, and is not intended as a handbook for their identification, there can be few of the commonest species which are not depicted among the 84 photographs in colour and 58 in monochrome, mostly taken by Paul de Laszlo; and many of these are common woodland fungi which can be identified immediately from the photograph. Fungi are peculiarly difficult subjects for colour photography and printing, owing to their extreme subtlety of tint, and inevitably there are a few failures. I should include Plates 2, 3, 18*b*, 26*a*, and 38*b* among them. But taken as a whole this is by far the best collection of colour photographs of fungi which has yet appeared in print, and indeed is probably the first which is accurate enough to be useful to those who want to recognize the species.

SOCIETY'S AND OTHER NEWS

HONOUR: MR. R. A. GALLOWAY, M.C.

Foresters everywhere will be delighted that Mr. Galloway's signal services to forestry have been recognized by the inclusion of his name in Her Majesty's Birthday Honours List this year. Mr. Galloway is made O.B.E.

Writing recently in *Scottish Forestry* on the occasion of the Centenary, the President of this Society remarked that both The Royal Scottish Forestry Society and ourselves 'are happily served by the same Secretary and Treasurer' and indeed it is fortunate that Mr. Galloway has been able to serve both Societies in this way for so long a time—in the case of our own Society since its beginning 28 years ago. We offer him our congratulations and our very best wishes.

ANNUAL GENERAL MEETING AND EXCURSION, 1954

The meeting in 1954 is to be in the South-east of England with headquarters at Bognor Regis and will be held from Monday 20 September to Friday the 24th. Through the kindness of owners of woodland and of the Forestry Commissioners a programme has been drawn up which will include visits to the following. 21 September, the Cowdray estate for the growth of conifers on various soils and for chestnut coppice. 22 September, Slindon (National Trust) for beech and Slindon (Forestry Commission) for treatment of old coppice woods, and to the Arundel estate to see beech woods and coppice. The annual general meeting will be held on the evening of the 22nd. On the 23rd, the beech woods at Charlton Forest, West Dean, and Goodwood will be visited and there will be a discussion in the evening. Members will disperse on the 24th but an opportunity will be given on that day for members who wish to do so to visit the Queen Elizabeth forest at Buriton

near Petersfield or the Forestry Commission Research Station at Alice Holt near Farnham. Attention may perhaps be called to two items in this number which are concerned with beech. Mr. Troup's paper *The afforestation of Chalk Downland* and Dr. Jones's review of the Forestry Commission bulletin *Studies on British Beechwoods*.

ANNUAL GENERAL MEETING AND EXCURSION IN NORTH WALES, 1953

The Society met at Llangollen, when the 26th Annual General Meeting was held on the 23rd September with the President, Mr. A. H. Gosling, in the chair. Some time had to be spent at this meeting over the election under Articles X and XI of the constitution of office bearers and councillors for the coming year due to the non-receipt of nominations from members. Written nominations are asked for under Rule 3 to reach the Secretary on or before the 30th April in each year. A motion was put forward at the meeting (The Hon. J. W. Best) suggesting the maintenance by the Society of a list of qualified consultants. During the discussion it was obvious that difficult implications were involved, and on being put to the vote the motion was defeated; but at the suggestion of the President the subject was referred to the Council for further consideration. Ninety-three enrolled for the meeting and excursion and nearly as many attended. Over sixty were present at the discussion on the last evening.

The excursion was carried out in splendidly fine weather and was extremely well run by Professor E. C. Mobbs who was on familiar ground. The Society has also to thank the owners of the private estates visited for their kindness and hospitality, and the Forestry Commission in Wales from Mr. A. P. Long downwards.

The woodlands at Powis Castle were the first to be visited. The magnificent tree growth on these soils is world famous and the time here was rightly spent on the examination of individual trees and groups of trees. Some noteworthy examples were the Red Rock Oak; height 80 feet, q.g. b.h. 53 inches, and timber volume 680 cubic feet. The Lady Harriet Oak; length of clear bole 53 feet and cube 353 feet. The Gold Cup Oak Wood of 35 acres of pedunculate oak, 60 trees to the acre, which measured in 1939, 3,240 cubic feet to the acre and lastly 'the tallest tree in Britain', a Douglas fir 107 years old and 170 feet high with an estimated cube of 560 feet. Thence members proceeded to the Leighton estate where the owner (Mr. C. P. Ackers) discussed with them the problems of thinning to obtain high-quality timber and the dangers of wind-blow. *The Times* of 26th September published a remarkable photograph under the heading *Redwood Trees on a Montgomery Estate* which showed members examining the well-known group of *Sequoia sempervirens* at Leighton. These trees at 100 years of age have an average cube estimated at 200 feet. The last private estate visited was the Vivod estate (Mr. H. G. Best) where the extremely interesting mixed woods in the Dingle were seen and the problems of extraction discussed.

The two state forests visited were Gwydyr and Cynwyd. The stage reached in North Wales has been well described by Mr. Cadman in his paper *Forestry and Silvicultural Developments in North Wales* which was prepared for the meeting and was included in a recent number of *Forestry*. Messrs. Scott and Macgregor's paper *Fast-Grown Wood* in the same number of *Forestry* also had considerable bearing on the problems which were dis-discussed in the woods and on the final evening. Both can be referred to for further information.

The emphasis in forestry in North Wales, and indeed elsewhere in Britain, is turning from the problems of afforestation to the problems of the disposal of small thinnings, to the kinds of timber to grow in final crops, and to extraction and conversion. We were therefore

particularly glad that Mr. Gordon Jacob was able to take part in the discussion on the last evening at which the Vice-President, Mr. Hiley, took the chair.

The subject for the discussion which was opened by Mr. F. C. Best was 'Should we grow our trees quickly?' Mr. Best said that four things were important here; (1) the selection of the planting site; (2) the species chosen; (3) the spacing and initial treatment before the closing of the canopy; and (4) after canopy formation, the degree of thinning within normal silvicultural practice. Such thinning would not affect total production, but light thinnings conserved the ground and gave cleaner timber whereas heavy thinnings gave larger diameter. We had to consider what effect heavy thinnings had on the quality of the timber grown. With larch it was difficult to keep diameter increment going without heavy thinning. Did underplanting help? Or did it take too much out of the ground even in a wet climate such as we had in Wales? We might aim at two-story crops either by underplanting or by mixtures, or by crown thinnings.

Mr. G. B. Ryle felt that private forestry, where planting cost the owners £40 to £50 per acre, could only pay if substantial early revenues were ensured. This meant heavy thinnings and perhaps the development of two-storied plantations. It would be a pity if the understory were permitted to oust the first crop as this would lead to a preponderance of shade bearers and such valuable species as larch would tend to go out. Under systems of natural regeneration in uneven aged woods, this was almost inevitable.

Mr. M. J. Penistan held that the methods adopted at Leighton gave great length but would mean a wide-ringed core and narrow-ringed outer edge producing timber that would not behave well. On the other hand at Gwydyr, policy favoured the big rough trees. In striving to meet requirements, we must turn to early crown thinnings and then let the best stems go on. In east Scotland we were concerned with the production of quality and the big rough trees must come out early. Crowns must be kept long. Our best crops may come in partial shade, i.e. by interplanting by stages. We could keep intolerant trees such as larch if we introduced them late enough in the interplanted stand when the over-story was thin on the ground.

Mr. Hampson said that at Dovey, which the Society had not seen, management was very different from Gwydyr. At Gwydyr, stocking was low and crowns dense. At Dovey, they went at once for the dominants and retained much of the rest. After about three thinnings there were about 200 stems per acre of freely growing dominant trees for the production of millable timber in the shortest possible time, with a second story thinned with reserve to provide higher quality close-ringed timber and which might be completely cut out to meet an emergency demand without danger to the dominant final crop overhead. The second story also acts as a stem-cleaning crop to the widely spaced dominants.

Mr. Langshaw Rowland thought that while we would never have enough timber, it was difficult to know in what form it would be used. If, as he and others thought likely, there was a great future for laminated wood, then clear timber was necessary as knots were the abomination of the peeler. If, on the other hand, the future was mainly for moulded wood, then rough timber would do. The only safe thing was to take the middle course. He felt that pruning was done too late. Great caution should be shown in pruning hardwoods. The pruning of very old oaks at Powis was a disaster from the point of view of their value as timber. Yesterday they saw beech pruned at 15 years which was too late. With hardwoods, the value is in the butt. Thinning should be heavy to get big crown and big bole. He did not agree that highest-quality softwoods should be aimed at in Scotland. The high quality of the Baltic timber was from virgin growth and would not be repeated.

Mr. J. T. Smith, speaking solely of softwoods, said the essential thing was to grow uniform-sized timber with even ring width, whatever method was adopted. The trend in soft-

woods was towards wall boards, &c. and timber would probably be most wanted in small sizes. If it were possible to grow a small percentage of high-quality timber, it would certainly pay its own reward.

Mr. Jacob held that the forester and the timber merchant must get closer together. As far as hardwoods went, there was no real problem. We should grow them as fast as possible and produce good clean butt lengths of large girth, 20 feet or so in length, and not always grow for particularly long lengths. Large girth is the primary consideration here.

With regard to softwood it was different. In Scandinavia the trees converted were from 5 inches to 14 inches or 16 inches diameter and they had developed a very efficient technique for dealing with this size. We must in this country think of our sawmills working at a low cost of conversion and this could only be done, as in Scandinavia and other countries, by a flow of timber within a reasonable range of diameter sizes, and he would suggest that the size should be 10 inches to 16 inches diameter, or if it must be bigger (as was suggested by Mr. Betterton for reasons of management) then let it at any rate be within one range of sizes. When all was said and done the average size of sawn timber used in this country was roughly 2 inches by 5 inches. We must think of marketing converted timber in the largest size possible, and not think of breaking it down to build it up again. To think of growing our wood mainly for sale as pulpwood would mean that we were growing for a lower priced market. We should go for the higher-priced markets such as sawn timber whenever possible.

He had no quarrel with pruning but could not see how it could be carried out from a labour point of view or whether it would be worth the trouble as, even when the planting programme was completed, we would still have to import 70 per cent. of our softwood requirements. The 30 per cent. that we grew in this country should find a market in normal constructional requirements, box and crate market, &c. We should grow our softwoods for bulk and import the better quality.

Mr. Garfitt suggested that the insistance on uniform-sized timber made by the last two speakers hardly took into account the scale of production likely. There would not only be the final crop but all sizes of thinnings as well. A range of mills would be required to deal with all sizes.

Mr. Hiley welcomed Mr. Jacob's appeal that foresters and timber merchants should work more closely. Foresters could grow timber with a wide range of size and ring width, but there was also a wide range in the cost of growing it. Timber merchants should tell us the relative value to them of different sizes and qualities and we could then grow to specifications which best matched cost with sale price. Thinning régimes that aimed at six or seven rings to the inch would be very different from those in the new yield tables.

In summing up, Mr. Best admitted that there was some conflict between growers and users which could only be settled by discussion. He thought the meeting did on the whole support the policy of bulk production as practiced in Wales. Others who took part in the debate included Messrs. Banner, Maxwell Macdonald, Stocks, Betterton, Maciver, Godwin, Edlin, Sir Gerald Trevor, Messrs. Macgregor, Harker, Workman, and Sir George Campbell who said that he was pleasantly impressed by what he had seen of the Forestry Commission thinning technique in North Wales, which equalled and perhaps surpassed that presently practiced in the West Highlands of Scotland. He added that he was glad to see that Wales was cashing in on its obvious potentials, a remark which probably expressed pretty well what most of those present were thinking.

[*continued from inside front cover*

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